ENGINEERING CASE LIBRARY

ECL 2

NOTE ON PUNCHED CARDS

An Engineering Case

Prepared in the Design Division of the Mechanical Engineering Department, Stanford University, by Bernard Roth and Karl H. Vesper, as a basis for student projects with financial support from the National Science Foundation.

NOTE ON PUNCHED CARDS

Introduction

Punched cards are familiar record keeping devices in accounting systems. They are also widely used in computer systems as a "common language" medium,that is a medium through which machines can communicate and be instructed. Other common language media, less used than punched cards are punched paper tape and magnetic tape. Most larger computer systems, as illustrated in Exhibit 1, include punched card equipment as at least one alternative communication medium.

Cards are read by machines from the pattern in which holes are punched in them. Most card reading machines pass cards edge-wise through a set of tiny wire brushes, each brush being aligned with a different row on the card. When the hole of a card passes over one of the brushes, that brush projects through the hole to meet an electrical contact on the other side of the card and thereby closes an electrical circuit. Another method is to sense the hole photoelectrically.[1] Either reading method can be performed at high speed. The sensing units can have very low inertia for fast response, and cards can be read "on the fly," without stopping. Reading speeds of over 600 cards per minute are common.

Punching of cards can be done either manually with a keypunch, or automatically. Manual keypunching is the most commonly used way of preparing initial data for input to accounting systems or computers. The keypunch operator prepares cards using a keyboard similar to that of a typewriter. Such a machine is illustrated in Exhibit 2. The speed of punching is limited by the human operator, and is many times slower than a reading machine can accept the cards. For this reason, a single computer is often backed up by one or more rooms full of programmers and keypunches.

Automatic card punching machines are used as direct outputs from computers and as card reproducers. The output of a digital computer may be on any of the common language media, or it may be displayed

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1 The old player piano read the holes punched in its roll of music pneumatically. For each key of the piano, there was an orifice across which the paper passed. These orifices were all in a line across the music sheet. For each note to be played, there was a hole in the sheet, and when that hole passed over its orifice, it allowed air to pass through from the orifice and the resulting pressure change signaled the key to depress and play the note.

directly, as on a high speed printer, a graph plotter or a cathode ray tube. Cards have the advantage of flexibility as unit records which can be shuffled or sorted. They have the disadvantage of being slow, at least relative to magnetic tape.

Card punching is usually done with a steel punch and die. The card is gripped between rollers which position it and hold it still while a punch, driven by an eccentric shaft or a cam pokes through the card into a die, producing the hole.[1] The inertias involved in punching mechanisms are higher than those of reading mechanisms. Also, in punching, the card is stopped at each hole position before moving onto the next, so that time is required in acceleration and deceleration for punching which is not required for reading. Consequently, automatic punching, though faster than manual punching, is performed much slower than reading, generally not even one third as fast.

Since speed is such an important characteristic of computer systems, and since the use of cards is expected to continue in such systems, most manufacturers of punching machines continue to seek ways to design more speed into their punching machines and to consider other ways in which the function might be accomplished better.

History of Punched Cards

Punched cards were first used to mechanize weaving machines by a Frenchman, Falcon, in 1728. In this application, the pattern of holes in each card, determined which threads would be lifted as the shuttle crossed the loom and thereby determined the weaving pattern. A series of cards were linked together and the machine advanced them so that a different card controlled the strings for each passage of the shuttle. The machine, now known as the Jacquard loom, was the invention of a succession of minds during the 18th century. Its use was adamantly opposed by silk weavers of the time who feared loss of employment, but it was quickly successful and is today still widely used.

Charles Babbage, a professor of mathematics at Cambridge University, proposed use of punched cards around 1830 to control the operation of a mechanical calculator called a "difference engine." This was a device to compute mathematical tables by adding sequentially a set of the successive differences between numbers. Development of the machine required engineering work which was underwritten by the British government. Before the project was completed, however, the government withdrew its support and the machine was left unfinished, although its principles were sound and a limited model had been operated.

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[1] The force required to push a punch through a card is around 6 to 12 lbs. statically, depending on the face angles of the punch. No data on dynamic forces required were available.

A statistician at the U.S. Census Bureau, Dr. Herman Hollerith, made possible the first use of punched cards for the large scale data processing during the census of 1890. In his machine, rows of telescoping metal pins dropped through the holes in the cards from above into mercury cups beneath. Electrical circuits were closed by contacts between pins and cups and caused the movement of counter wheels. The operation was not highly mechanized. Each card had to to positioned by hand over the cups. But the 1890 census of 62 million people took only one third the seven years that the 1880 census of 50 million people had taken.

Development of other card processing machines for the Census Bureau, including the first key punch, the first sorter, and the first tabulator, followed the use of Hollerith's first machine. Pictures of some early machines appear in Exhibit 3. Commercial use of the machines began with their application to railroad accounting systems.

Hollerith formed a company to manufacture his machines. In 1911 his company merged with two others to become the Computing-Tabulating Recording Company, CTR. This company, the name of which was changed to International Business Machines (IBM) in 1928, continued to develop new machines for processing cards, including an improved tabulator which would add columns of information from decks of cards and print the results automatically in 1920. In 1924 a machine was introduced which would make 400 cards per minute. In subsequent years, its speed was raised to 650 cards a minute, then 800 and finally 1300 cards per minute.

During the 1930's punched cards found increasing use in accounting systems, as machines were developed which would handle alphabetic as well as numerical information. In 1936 the Social Security System set up accounts for 30 million people using punched cards.

In the 1940's,electronics began being introduced into punched card systems to speed the performance of calculations. At the same time, punched card accounting machines were made which could perform more calculating functions, including subtraction, multiplication and division as well as addition. Exhibit 4 shows an accounting machine of 1941.

With the introduction and development of automatic digital computers following World War II, punched cards found still more applications for input, output, and storage of information. Largely because of its dominance in punched card equipment IBM was able to come from behind in the digital computer market, entering in 1953, three years later than Remington-Rand, Univac, and within only three years was able to become the leading producer of digital computers.

The computers were capable of operating faster than the punched card input-output machines, however, especially after the electro-mechanical relays of early digital computers gave way to electronic logic circuitry. Consequently, ways of speeding up input and output were sought. A continuing search began for ways to handle cards faster, and also magnetic tape systems were introduced for input and output. Magnetic tape is substantially faster

than punched cards and also more compact, but it lacks flexibility needed for some applications. It cannot be used, for instance, as a payroll check or a utility bill the way a punched card can. Punched cards also have the advantage of being firmly established and widely used due to their long history.

The use of punched cards continues in accounting systems and also in computer applications. Large computer systems usually have alternative input-output machines, including punched cards. Sometimes the information goes from the programmer to punched cards, to magnetic tape and then to the computer. Sometimes the cards are read and punched directly by the computer. But cards are used in some way with the great majority of systems. An example of a punched card input-output unit for a computer, the Remington-Rand 1107, appears in Exhibit 5.

Physical Dimensions of Punched Cards

The most frequently used punched card is the IBM card measuring 7-3/8 by 2-3/4 inches. A sample IBM card is attached to Exhibit 6. Such a card sells for about one dollar per thousand. This card has positions for 960 holes, arranged in 80 columns with 12 hole positions each. The customary way of identifying hole positions is to number the rows starting with row 12 at the top, row 11 beneath it, row 0 beneath row 11, followed by rows 1,2,3, down to 9 at the bottom. Columns are numbered simply 1 through 80.

Overall dimensions of IBM cards were originally chosen to match dollar bills of the time. Early cards had 50 columns and round holes. To increase the information contained per card 100 columns were tried, but the card was thereby weakened too much, so the number was reduced to 80. Other companies have introduced different cards. Some Remington-Rand cards have 90 columns and round holes, and some European machines use smaller cards. However, the IBM card continues to dominate.[1] An attempt is now under way by the American Standards Association to standardize cards in the IBM format. Excerpts from the proposed standard appear as Exhibit 7.

Many coding systems are possible for writing on punched cards, as is suggested by the fact that there are 4,096 possible punching combinations on each of the columns of an 80 column card. In the simplest system to visualize, each row stands for its customary number from 0 through nine. Letters can be indicated by two holes each, one punched in the rows 0, 11, or 12, and the other in one of the remaining rows. For example "B" is represented by a hole in row 12 plus one beneath it in row 2. This code, known as the Hollerith code, is illustrated by the card of Exhibit 6.

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[1] IBM became so dominant in the punched card business that the Department of Justice undertook antitrust action against the company. A consent decree resulted under which IBM agreed to divest itself of all but 50% of the industry's card making capacity by September, 1963.

Hollerith code is used in accounting systems as also shown in Exhibit 6, and most other non-computer applications.

For computer applications, binary card codes have been developed. These binary codes have two advantages. One is that they allow more information to be packed onto each card. The other is that they are more compatible with computer logic. Binary logic is most convenient for computer circuits since these circuits are built of devices which have only two states, such as open-closed, energized-non-energized, or magnetized-demagnetized. Binary code on cards can be written either row-wise or column-wise. Also, a word may be continued onto part of another row or column, and the next word can pick up where it leaves off. Words are usually made all the same length, however, such as 36 bits, so that each card has the same number of words located in the same positions as words on the other cards of the program.

Automatic punching machines are used to punch all types of codes. A punching machine may operate as the direct output of a computer, it may be the output of a translating device which is taking information from some other medium to be put onto cards, or it may be simply duplicating other cards.

The nature of the code may affect the load on the punching machine. Binary codes, for instance, generally require that more holes be punched. With Hollerith code, on the other hand, fewer holes in total per card are punched, but there tends to be a concentration of punching in the zero row of the card. Partly, this is due to the fact that zero occurs three or four times as often as any other numeral. And partly it is because programmers sometimes follow the practice of striking a zero to any column not otherwise used in the message being put on the card. By so doing, they can check to see that no column has been missed or overlooked during the writing process.

Future of Punched Cards

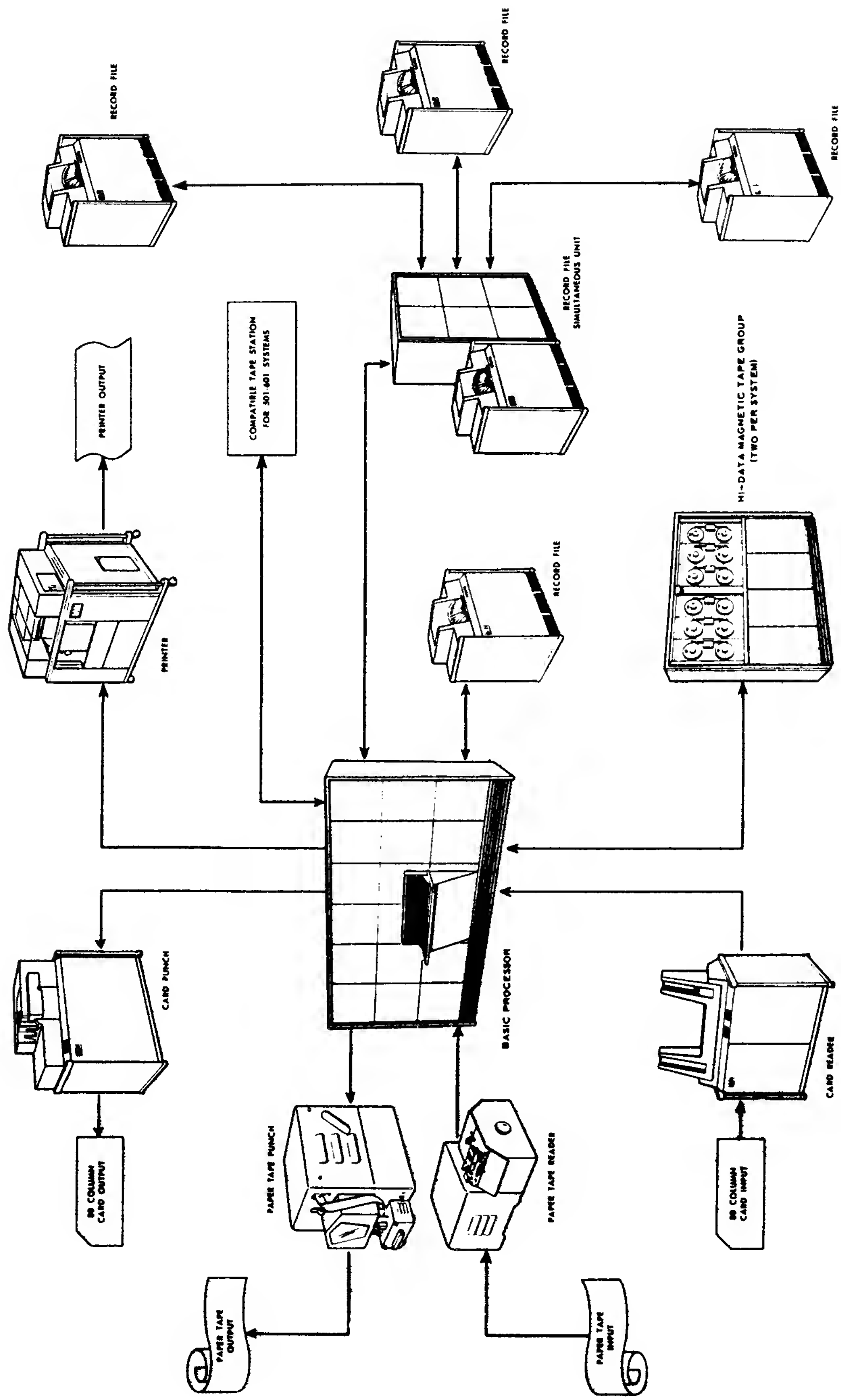
When magnetic tape was introduced to computer systems in the late '50's, there was conjecture in the data processing industry that it might soon replace cards as a common language medium for computers. Not only are tapes many times as fast an output recording device as cards, but also they are more compact: a 10-1/2 inch diameter roll of tape possible holding as much information as 50,000 punched cards. Moreover, a tape may be expected to last indefinitely and can be erased and reused whereas cards cannot be reused and they wear out.

Cards have, nevertheless, continued to be used in ever increasing quantity. In some ways they are more flexible than tapes. The cards of a program can be rearranged, or certain ones can be withdrawn or modified

without changing the whole deck. Unlike magnetic tapes, cards can be visually inspected, and they can be written on, as in the card in Exhibit 6, for visual identification. Cards have proven very useful as "return documents," such as payroll checks, utility bills, class enrollment cards, etc.. The same card can thus be used both in a "common language" capacity and as a written document. A user need not have a major data processing system to use cards, but can begin with a simple card system and gradually adapt it to increasing complexity as his needs grow.

Punched cards began early, and have since become increasingly intrenched as a common language medium. The number used per year has continued to grow and is expected to grow further in the future. A question unanswered for the future is how the machines for handling cards will be improved.

Exhibit 1 - Computer systems



INPUT-OUTPUT EXPANSION OF THE RCA 301 DATA PROCESSING SYSTEM

Reproduced from Office Automation Handbook, 155 Fifth Avenue, New York 10, N. Y.

Exhibit 1 - Computer systems (cont.)

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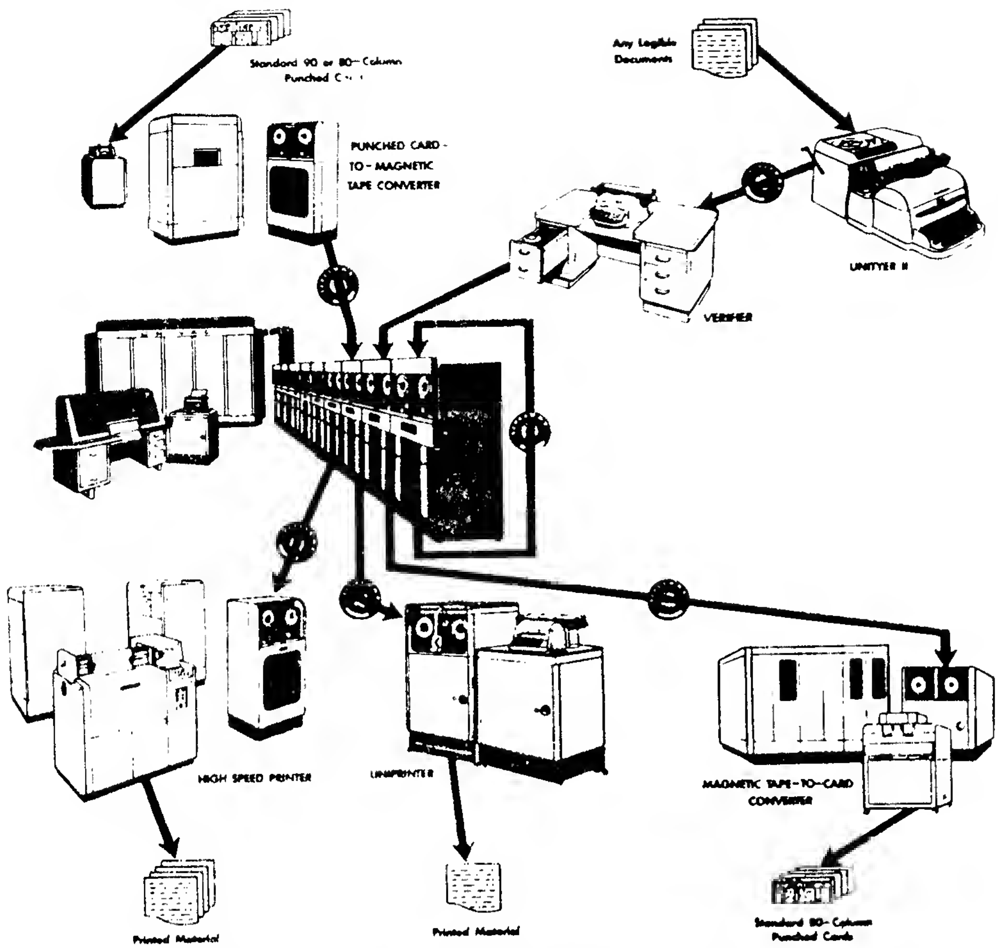
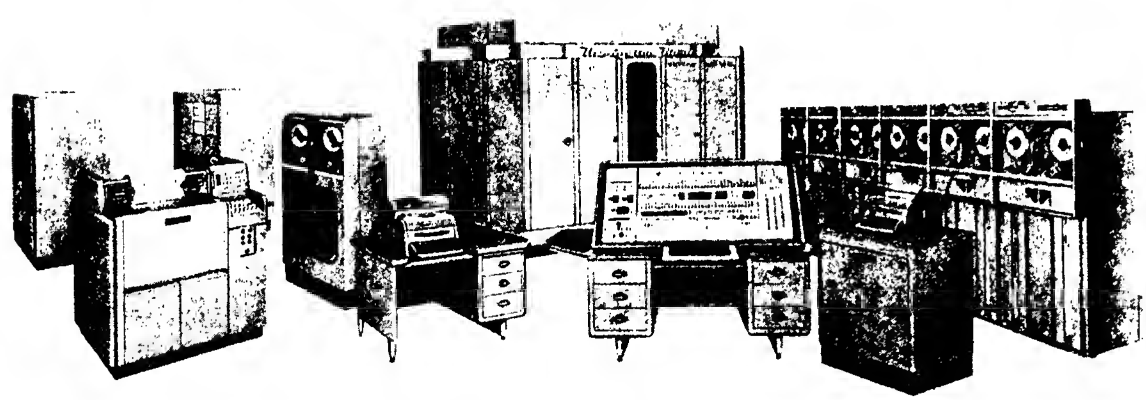


UNIVAC II DATA AUTOMATION SYSTEM

INPUT AND OUTPUT DEVICES IN RELATION TO CENTRAL PROCESSING UNITS



REMINGTON RAND UNIVAC II DATA AUTOMATION SYSTEM

Reprinted from Office Automation Handbook, 155 Fifth Avenue, New York 10, N. Y.

Exhibit 1 - Computer Systems (Con't.)

COMPONENT PRICES OF THE BURROUGHS B-5000 SYSTEM[1]

Basic Required System (does not include input-output units)

B-5280	-	Processor Module A	$265,600.
B-5282	-	Input-Output Sub-system	93,375.
B- 430	-	Storage Drum	70,550.
B- 460	-	Memory Module	51,875.

Peripheral Equipment

B- 122	-	Card Reader (200 cards per minute)	8,800.
B- 124	-	Card Reader (800 cards per minute)	15,200.
B- 303	-	Card Punch (100 cards per minute)	18,000.
B- 304	-	Card Punch (300 cards per minute)	27,000.
B- 321	-	Line Printer (700 lines per minute) (1 or 2 of these units may be used with the system)	49,800.
B- 422	-	Magnetic Tape Unit (66M characters/sec.) (Any number of these units up to 16 may be used with the system)	33,200.
B- 460	-	Memory Module (4,096 words) (Maximum of 8 modules)	51,875.
B- 141	-	Paper Tape Reader (1M characters/sec.)	16,800.
B- 341	-	Paper Tape Punch (100 characters/sec.)	9,500.

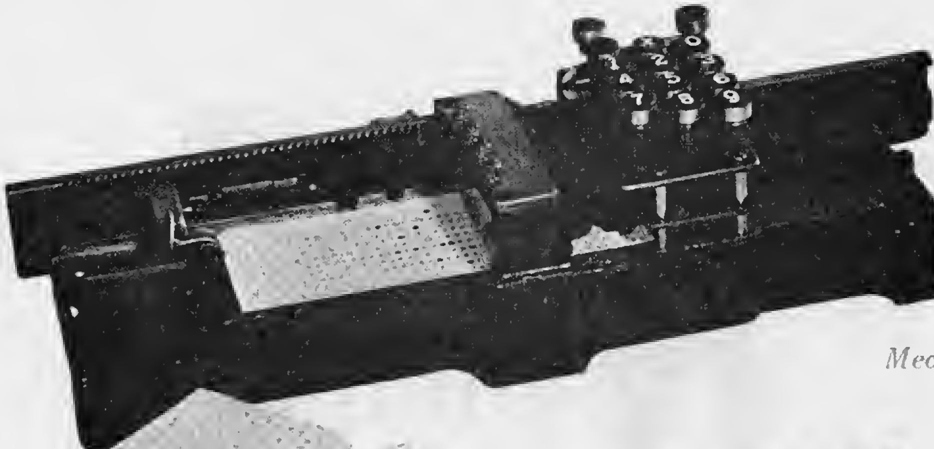
1 The Burroughs B5000 is described by the Burroughs Company as being "a medium priced, general purpose, solid state system that sets new standards of productivity. The B5000 is an integrated hardware-software package specifically designed to utilize the higher level languages of ALGOL and COBOL and thus reduce programming time and cost. Highest productivity per dollar is achieved thru multi-processing several unrelated jobs at the same time under the control of a comprehensive MASTER CONTROL PROGRAM that not only schedules and controls work but also assigns memory and input/output units."

Exhibit 2 - Manual Card Punch

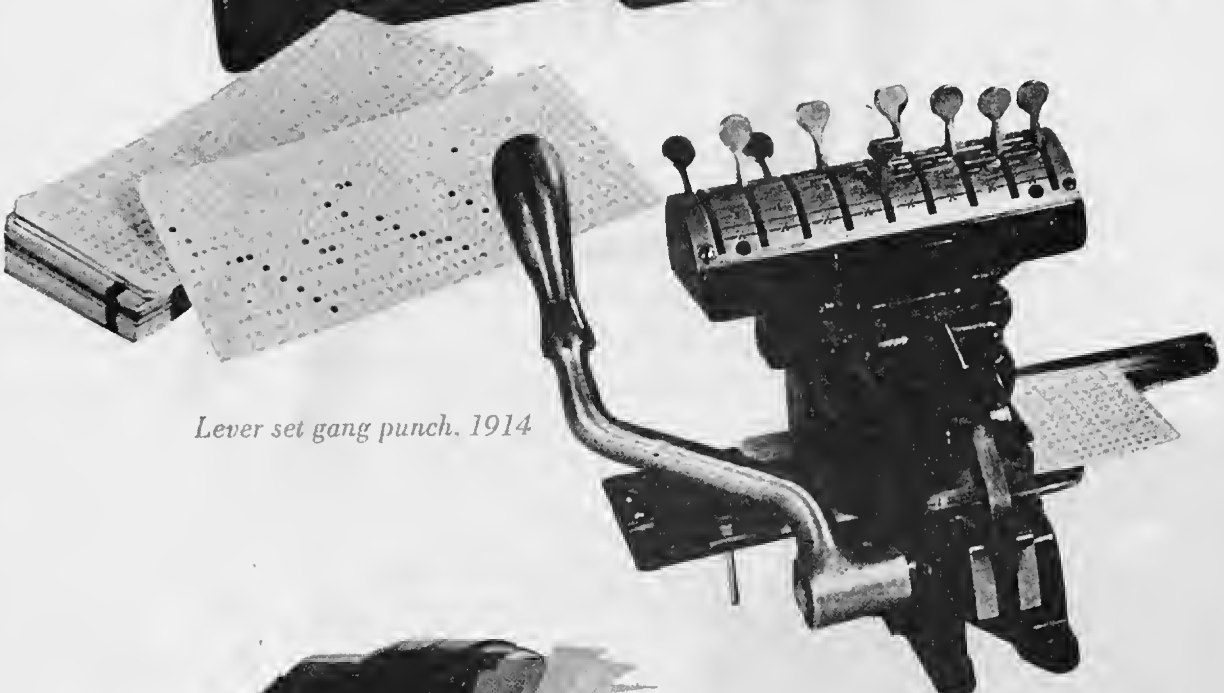
IBM 26 Printing Card Punch

Courtesy IBM

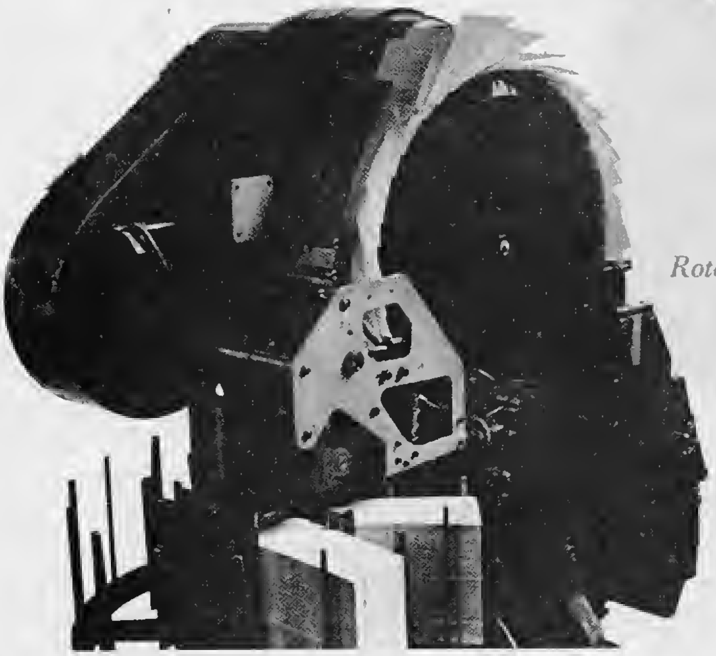
Exhibit 3 - Early Card Machines



Mechanical key punch,



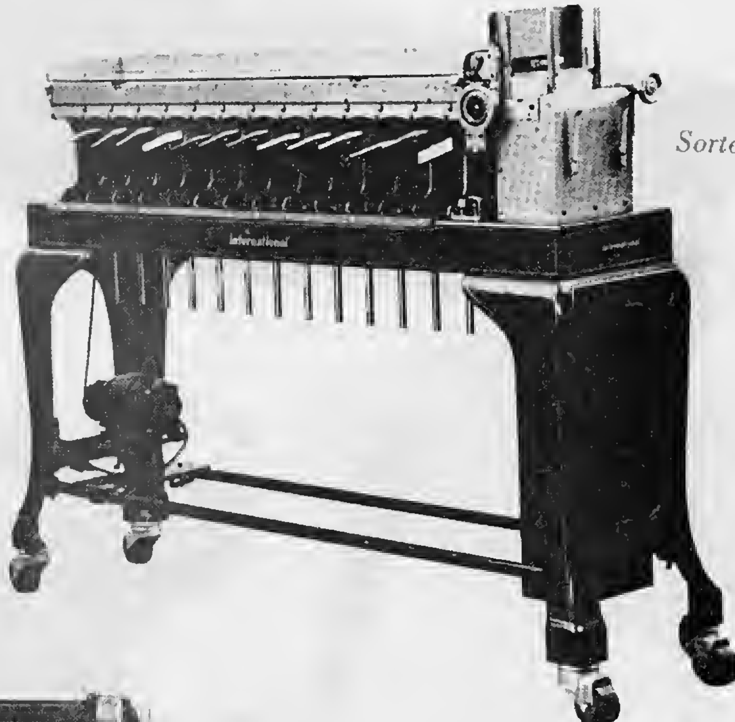
Lever set gang punch, 1914



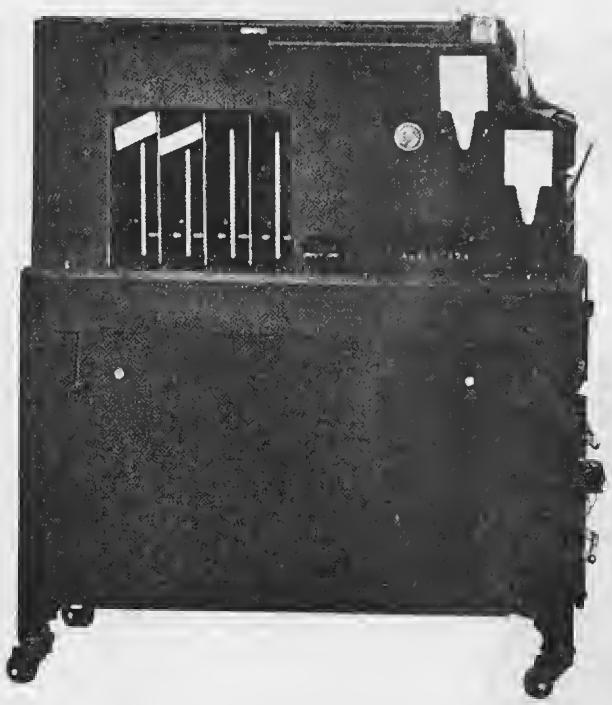
Rotary card manufacturing machine, 1936

Courtesy IBM

Exhibit 3 (Cont.) - Early Card Machines



Sorter, 1925



Collator, 1937

Courtesy IBM

Exhibit 4 - IBM Accounting Machine

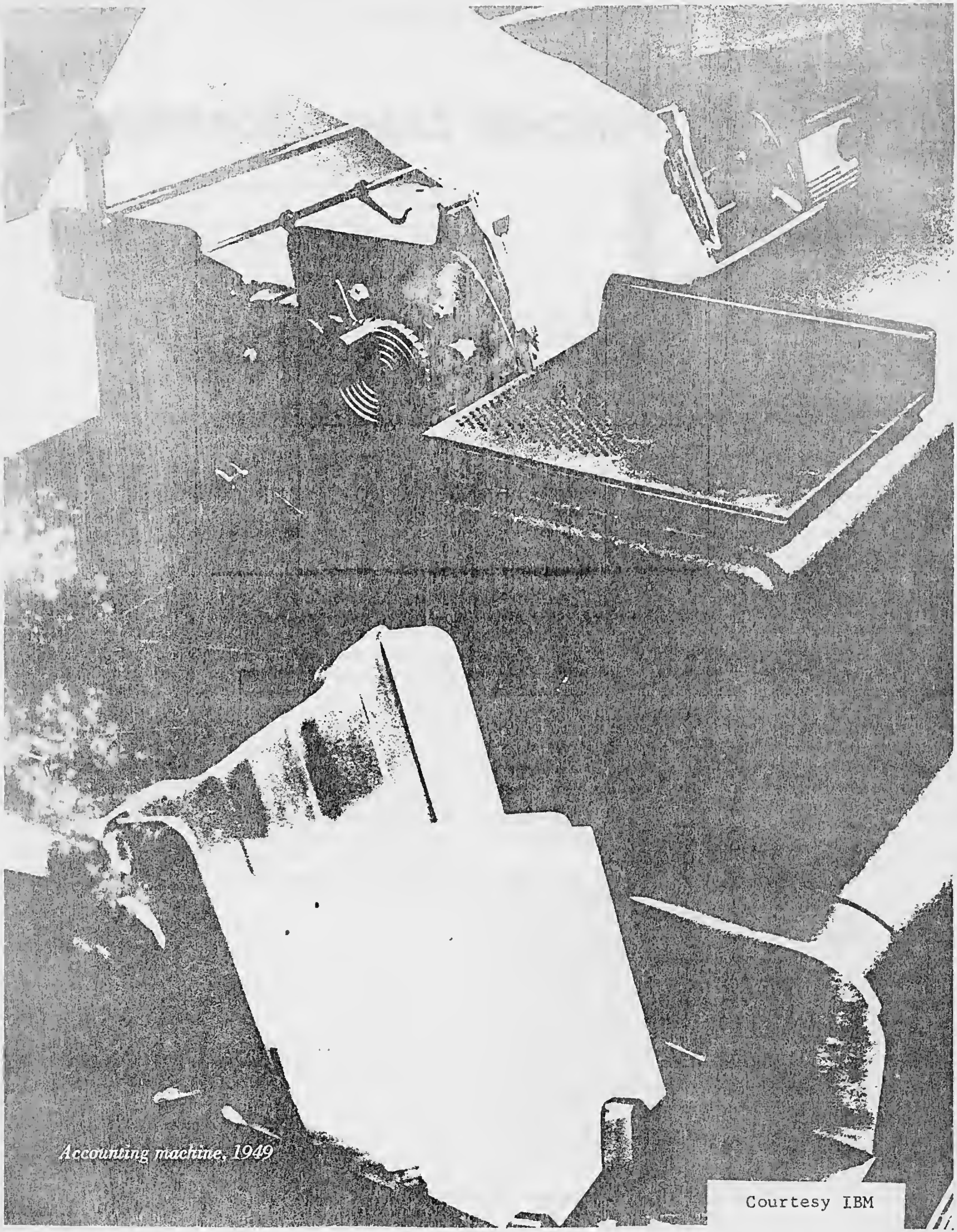
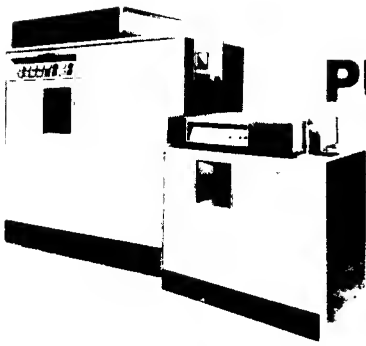


Exhibit 5 - Automatic Card Punching Machine



PUNCHED CARD SUBSYSTEM

The Punched Card Subsystem for the UNIVAC 1107 system comprises a Card Reader, Card Punch, Card Control Unit, and Channel Synchronizer. Using 80-column cards, the Punched Card Subsystem operates as a computer system input or output device, or both concurrently. The Card Reader can read and check at processing speeds of 600 cards per minute; the Card Puncher can punch and check at processing speeds of 150 cards per minute. By programming a 4-to-1 interlace (read four cards and punch one card), a user can effectively read and punch cards at a total rate of 750 cards per minute.

The Card-Reader unit has an input magazine, first read-sense station, second read-sense station, and three output stackers. Cards are fed on a roller mechanism, automatically read at the first sense station and verified at the second sense station, and deposited into the output stackers.

The Card Punch unit has an input magazine, a punch station, a wait station, a punch-verify station, and two output stackers. A punch operation normally consists of making a read-check (when applicable, using the special memory in the control unit), punching a card, and making a punch-verify check before depositing the card into an output stacker.

The Control unit, in addition to its normal control functions, contains a memory to store the contents of three cards (for comparison purposes) and to store card translation data.

Under normal operating conditions, the Card Reader will read a card every 100 milliseconds; the actual sensing and storing of data is accomplished in 82 milliseconds allowing 18 milliseconds unused time. The Card Punch unit normally punches a card in 400 milliseconds; translation, transfer, and set-up time preparatory to punch is approximately 266 milliseconds with the actual punch time 134 milliseconds. The 4-to-1 read-to-punch ratio makes it possible to read four cards for every one card being punched if such concurrent operations are programmed. When either the *Read* function or a *Punch* function is commanded with computer interrupt, that interrupt must be processed and completed before the next function can occur.

Programming The Punched Card Subsystem is programmed using Input/-Output instructions which transfer data between the core memory storage section of the Computer and the punched card subsystem. The data may be in one of three formats: card code, row binary, or column binary.

Card code punching means that each column used contains one, two, or three punches, representing an alphabetic or numeric character or a special symbol. Each of these is automatically translated (in the control unit memory) to a six-bit binary character such as Fieldata for transmittal to the Computer. Using this format, each card can furnish data for a block of 14 36-bit Computer Words.

Row binary punching means that each of the 12 card rows contains two 36-bit Computer Words, plus 8 bits. Words can be sent directly to the Computer without subsystem translation. Using this format, each card can furnish data for a block of 27 Computer Words.

Column binary punching means that each group of three 12-row columns contains a 36-bit Computer Word, which can be sent to the Computer without subsystem translation. Using this format, each card can furnish data for a block of 36 Computer Words.

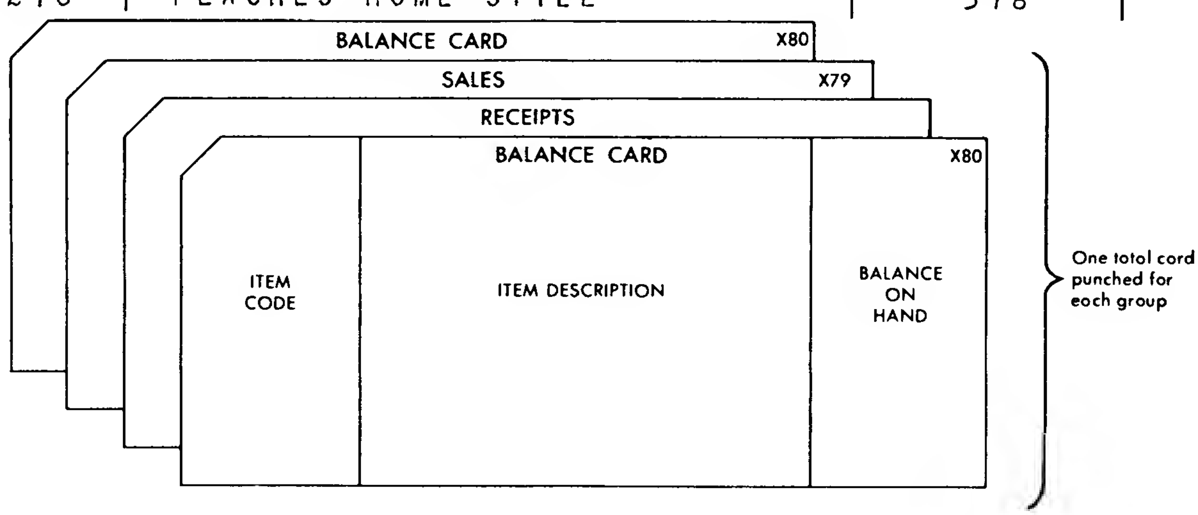
Courtesy Sperry Rand Corporation

Exhibit 6 -IBM Card and Application

The Stock Summary Report shown below was prepared on an accounting machine from total cards prepared on another machine. The total cards could be interpreted and used in place of the report, if desired. The balance-on-hand is obtained by adding receipts to old balance-on-hand and subtracting sales.

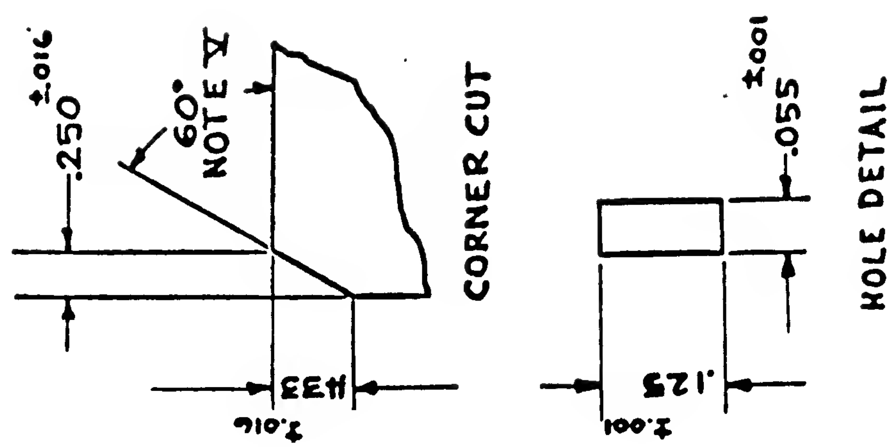
STOCK SUMMARY

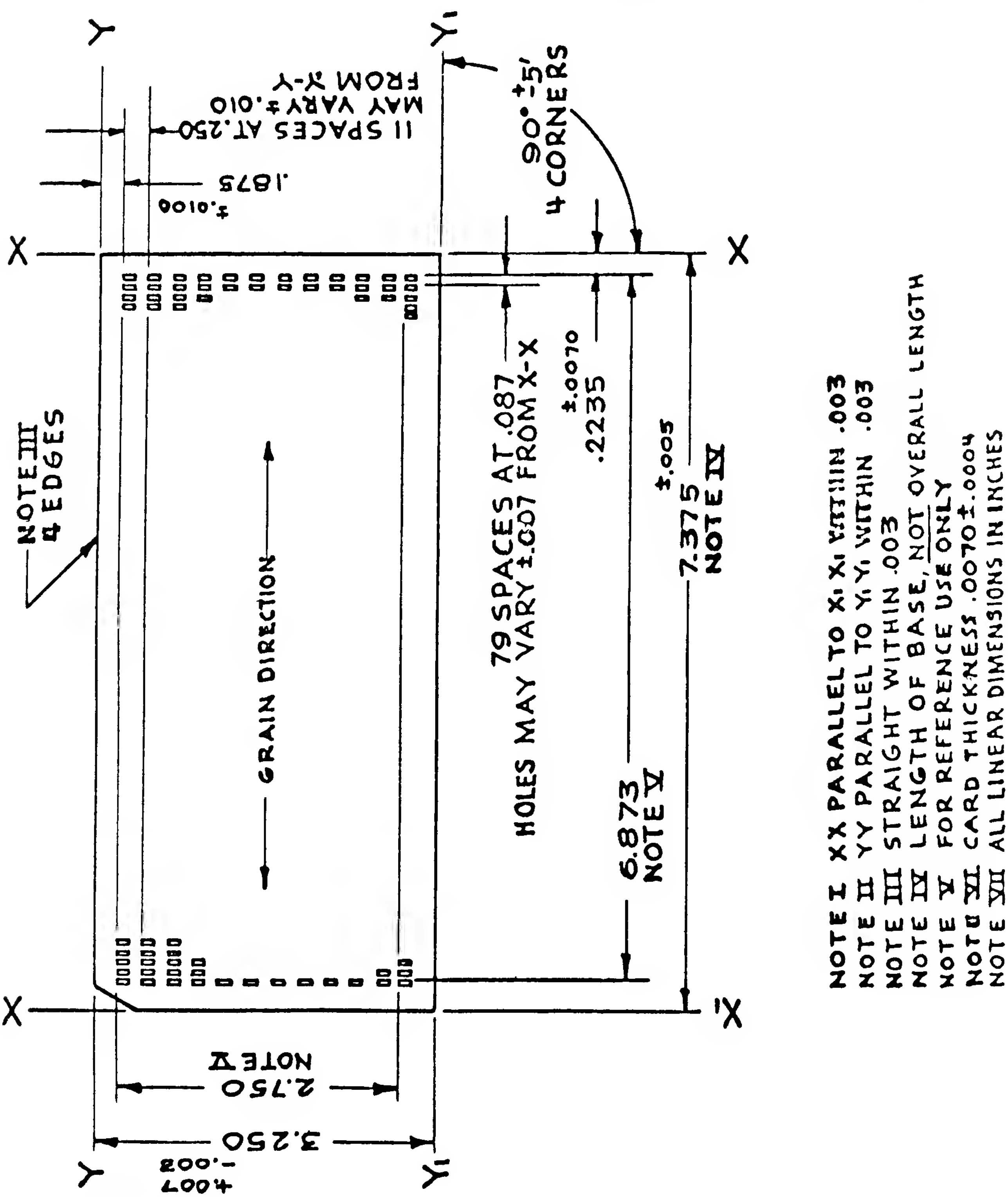
ITEM NUMBER	ITEM DESCRIPTION	BALANCE ON HAND
5238	ASPARAGUS GRADE 1	123
5257	BEANS	1007
5268	JELLY LARGE GRAPE	235
5276	PEACHES HOME STYLE	378



Courtesy IBM

Exhibit 7 - Proposed Dimensions of Punched Card Standard proposed by the American Standards Association, Inc.
(Reproduced by Permission)





ECL 3

ENGINEERING CASE LIBRARY

INTERNATIONAL BUSINESS MACHINES CORPORATION (A)

IBM and the Computer Industry

An Engineering Case

While International Business Machines Corporation has cooperated with Stanford in encouraging the development of this course material and in supplying basic information and documentation, the company has not reviewed the course manuals and has had no part in their preparation and therefore does not necessarily concur with any opinions expressed or attest to factual accuracy. IBM wishes explicitly to avoid such intervention in order to allow complete editorial freedom to the University.

Prepared in the Design Division of the Mechanical Engineering Department, Stanford University, by Bernard Roth and Karl H. Vesper as a basis for student projects with financial support from the National Science Foundation.

IBM

IBM and the Computer Industry

"Growth Company"

"Can IBM Keep Up the Pace?", asks the title of an article in Business Week magazine, February 2, 1963. The pace of IBM has been one of unusual growth. Worldwide sales in 1962 were over $2.5 billion or 3.6 times the total sales in 1955. During the same period, net income multiplied fourfold. Reflecting the stock market's reaction to this sales increase, the price of IBM stock increased sixfold in the same period, while brokers and investors referred to IBM as a "growth stock." In contrast, the U. S. gross national product rose less than half in the same period and the Dow-Jones Industrial Average only slightly more than one half. IBM stock was selling for $490 per share at the end of 1963 or 56 times the previous year's earnings. At the same time, the Dow-Jones Industrial Average had a price-earnings ratio of around 18. When stockholders place a high value on a company's stock it is usually because they expect the company to continue prospering and growing. And the stockholders elect the management which runs the company.

A variety of factors have been suggested as the keys to IBM's success. One analyst commented:

> "There are several interrelated reasons for IBM's growth today. Not the least among them is the selling muscle that still owes an immeasurable debt to Watson,Sr. But it is IBM's unparalleled educational program that has played the prime role in building IBM's ascendancy since the mid-fifties. The old electromechanical calculators were sophisticated accounting machines. But compared to the giant machines of the 1960's they were simple indeed..."[1]

The letter to shareholders of the IBM Annual Report dated January 22, 1963 laid emphasis on new product development:

> "The range of IBM's products and services has been extended steadily in order to meet the growing data handling requirements of our customers.
>
> "A new key-driven accounting system that can handle smaller business requirements with greatly increased efficiency was announced a few weeks ago, and a new low-cost computer that promises to bring advanced data processing to many firms for the first time was introduced earlier this year.
>
> "Our customers' needs for increasingly larger systems were also met with the introduction of two new products including one of the most powerful computing systems ever offered by IBM.

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1 Dun's Review and Modern Industry, July, 1963

"Substantial investments were made in the Company's research and development programs during 1962. These programs are designed to produce new IBM products and services for the future..."

Illustrations of some of IBM's research and development activities appear in Exhibit 1.

The Chairman of the Board of IBM, Thomas J. Watson, Jr., pointed to the choice of industry as being a major factor in the company's success:

"Our growth has be to related to the environment and the competitive situation. We had an excellent opportunity, and we think we've capitalized a bit on that opportunity. But whenever I find myself talking smugly about our progress, I remind myself that in many other industries we could never have done so well."

"Our field of business", according to one of the IBM company publications, "is information processing...". Within this general category, the company concerned itself with a large number of products and services. One division made electric typewriters and dictating machines. IBM had entered the electric typewriter market by acquiring the Electromatic Typewriter Company in 1934, and by 1960 IBM was estimated to be making over 60% of all office electric typewriters. Another division was established in 1962 to manufacture solid state components for use in the company's electronic circuits. Other divisions made punched cards, tapes and other data processing machine supplies, did advanced product research, provided data processing services, and produced a number of computer systems. A list of the IBM Divisions and their products and services appears as Exhibit 2. It was in the area of computers that the major portion of the company's growth had occurred.

In 1950 there were less than a dozen large electronic computers, and they were used mainly for scientific explorations. By 1963 computers had come into wide use by business firms and annual sales of electronic computers was estimated at around $3 billion per year.[1] IBM trailed competition in entering the computer business. Remington-Rand came out with the UNIVAC in 1950 by buying the small Eckert Mauchly Computer Company that developed it. IBM, which had turned down the chance to buy Eckert Mauchly, did not come out with its first machine, the 702, until 1953. A major advantage to IBM, however, was its dominance in punched card equipment. IBM dominance in punched card systems was so great that anti-trust action had been brought by the Justice Department resulting in a consent decree in 1956 requiring that IBM divest itself of enough card making capacity to reduce its share of the industry to less than 50% within 7 years. By applying its energies to computers, IBM soon rose to leadership in that industry. It was estimated that by 1963 IBM had installed over 10,000 electronic computers, over 3/4 of the world total, and more than 10 times as many as IBM's nearest computer competitor, UNIVAC Division of Sperry-Rand Corporation.[1]

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[1] Business Week magazine, February 2, 1963

Sperry-Rand is by no means the only competitor of IBM in the computer business, however. The attractiveness of the computer market to some other companies is illustrated by the entry of Royal McBee during 1956 through acquisition of a smaller company, the General Precision Equipment Corporation. A former McBee executive summarized the merger as follows:

> "Before the merger with Royal, McBee realized that with the appearance of computers, which represented the future, it had to get into the computer business. Our problem was how to do it. Remington-Rand had already started in the computer business; IBM was in it. We didn't have the engineering talent to start, and yet we realized that we were looking at a market of many millions of dollars and at a very large investment of go after it."

The result was merger with General Precision, which had some computer engineering experience to form Royal Precision. By 1961, the Royal McBee Annual Report was able to claim:

> "Approximately half of all installations of low-price general purpose digital electronic computers in the United States presently are Royal Precision products. In Canada, Royal Precision has more of such installations than all competitive models combined."

Not all companies which tried to enter the computer business were this successful. Underwood Corporation tried to enter the market in a way similar to that of McBee. The 1952 Underwood Annual report stated:

> "In October 1952, your corporation acquired the business of the Electronic Computer Corporation of Brooklyn, N. Y., one of the leaders in the field of designing and constructing electronic computers. This activity is now being operated as the Electronic Computer Division of Underwood Corporation. The electronic computers manufactured by this division are marketed under the trademark ELECOM.
>
> ....
>
> ELECOM is the first standardized, fully automatic electronic digital computer to be produced at a price which is within reach of a considerable market of industrial user.....It is for the use, among others, of scientists, engineers, and mathematicians, and will be extremely useful in many complicated mathematical computations."

Underwood also became the licensee of an English company to make punched card equipment. This equipment was to use smaller cards than IBM cards and was mentioned in the Underwood Annual Report as follows:

> "With these small and less expensive cards and correspondingly smaller machine equipment, the benefits of punched-card methods will be commercially available to medium and small as well as large businesses."

Underwood continued to develop still other computer equipment in the following year, including larger computer systems. However, the results were less than satisfactory, and the 1957 Annual Report stated:

"Early in 1957 an important change occurred in our policy concerning electronic computers. It was concluded that continued development and commercialization of large-size computers entailed greater risk and capital than the company could prudently afford and this work was discontinued."

In 1958 the company continued for the third year to lose money and the Annual Report gave a still more restricted objective in data processing:

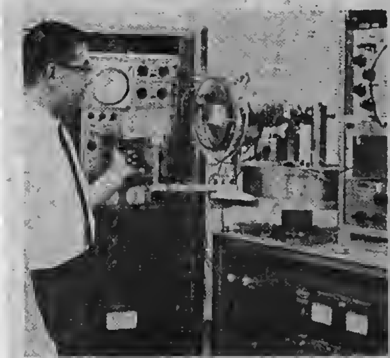
"Even though greatest effort during 1958 was devoted to the immediate problem of establishing a sound foundation of profitable operations, significant progress was also made in defining an attractive area for Underwood's future in the growing market for office automation....... Basically, our objectives lie in the area of mechanical, electromechanical, and electronic devices for the most rudimentary data processing requirements."

Losses still continued, however, and eventually Underwood was forced to sell out. A Fortune Magazine article describing the efforts of the chief executive officer, Frank E. Beane, to salvage the company described the end as follows:

"Beane finally admitted defeat in the spring of 1959, when a new adding machine, designed to replace the antiquated Sundstrand, had to be sent back to the drawing board for debugging. Without a first-rate product in the numbers field, Underwood hadn't a prayer of making out on its own...."

A number of firms have developed successfully in the computer business, however, and it is estimated that IBM now has around 375 competitors in this field. A list of some of them and their product lines appears in Exhibit 3. Some companies with interests in the computer business, such as Ford Motor Company, the owner of Philco, are much larger than IBM, as can be seen by the annual sales figures of IBM and some of its competitors appearing in Exhibit 4. In addition, there are smaller companies competing in various special types of computer peripheral equipment, such as the Soroban Corp. which makes a line of very high speed printers and punches. Thus, competitive pressures in product development continue to come from all sides. Some recent computer product introductions by two contestants, Minneapolis-Honeywell Regulator Company and General Electric Company are described in a reprinted Business Week article attached as Exhibit 5 entitled, "New Challenge to IBM."

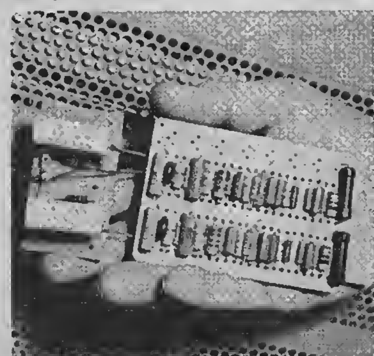
Exhibit 1 - Some IBM Research Activities

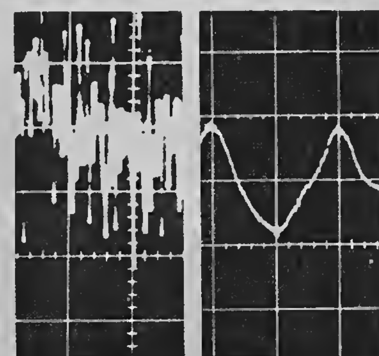


Electron-beam tube with removable faceplate permits controlled bombardment of recording material specimens. Materials are subjected to repeated cycles of recording, reading and erasing while in vacuum.

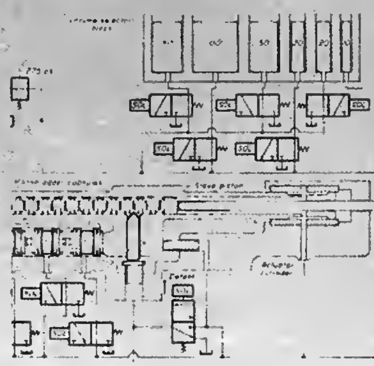
DC motor, left, developed by an engineer in San Jose, exhibits extremely high torque-to-inertia ratio and fast response. Designed especially for servo applications, the motor resulted from studies in electrical energy dispersion.

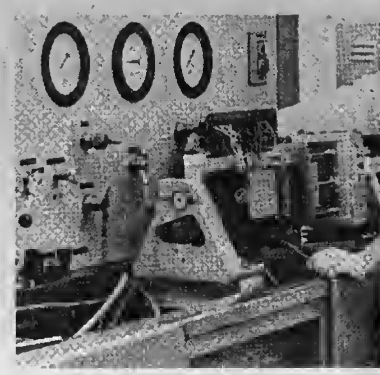
Matched correlating filter, right, developed in San Jose produces clear signal from noise-signal pattern (in next box). Composed entirely of linear passive elements, the filter was simulated first, then synthesized to determine precise component values on an IBM 7090 computer.





Unusual hydraulic actuator designed in San Jose laboratory is digital in concept. Motion increments of ten tracks are provided by volume selector block, smaller increments by piston adder capsules. Mechanical detent assures precision. Actuator at right is tested on hydraulic bench.

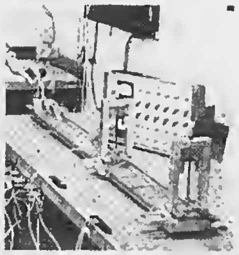




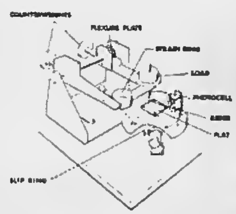
Laser technology, above, and Kerr-magneto-optic effect, have been combined by San Jose engineers to demonstrate optical recognition of magnetic recording. Continuous gas laser light is focused on reflective magnetic disk surface. Changes in polarization occur as the beam encounters magnetic information recorded on surface.

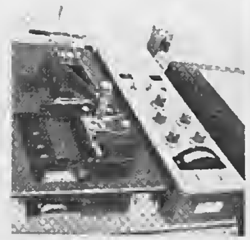
Courtesy International Business Machines Corporation

Exhibit 1 (Cont.) - IBM Research Activities



Wear, friction and electrical noise in sliding systems are studied with the help of this apparatus (schematic and picture right). Results give designers fundamental guide posts.

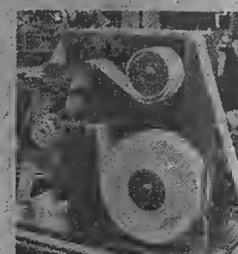




Printing 1,000 words per minute is feat of experimental terminal printer. Matrix of 35 wires is actuated by solenoids; prints one character at a time. Incremental feed for paper and carbon contains 36 moving parts.

Mass spectrometer is but one of the more sophisticated pieces of equipment available for work in the laboratory. This is operated by the advanced technology department.

High speed electrostatic clutch is key element in 3,000 line per minute printer built for experimental purposes. Dot printing occurs at intersection of clutch-driven bar and rotating helix. Clutch operates 198,000 actions a minute.



However simple a problem is at the outset or its solution seems, the investigation invariably involves mathematics worked out here on a blackboard and perhaps finally on a computer.

Liquid scintillation counter detects and measures beta radiation from liquid or solid specimens. Unit was designed and built in Endicott. Solid-state, nanosecond speed circuitry provides extremely accurate measurement.

Exhibit 2 - Divisions of IBM

General Products Division -	Largest IBM division, Manufactures small and medium computers and data processing systems, primarily for business applications. Products include the 1401 and 1620 computer systems and handling equipment for punched cards and punched paper tape used with larger computer systems.
Data Systems Division -	Manufactures larger computer systems such as the 1410 and 7090, primarily for business applications.
Data Processing Division -	Primarily concerned with sales. Sells machines on either outright purchase basis or rental basis. Provides maintenance as part of rental service or on a contract basis through an organization of "Customer Engineers". Performs systems engineering to uncover customers needs for computers, develops programs and maintains a program library for customers.
Federal Systems Division -	Handles sales to US Government, mainly using existing products but also doing some new product development.
Electric Typewriter Division -	Manufactures and sells electric typewriters, dictating machines and other small office machines.
Supplies Division -	Manufactures and sells punch cards, magnetic tape and paper tape.
Components Division -	Manufactures electronic components such as transistors, magnetic cores, and circuit cards for use in IBM products. About two years old.
Industrial Products Division -	To manufacture and sell non-computer products developed as byproducts of the company's development efforts and knowhow on a wide front of technology. Started only within recent months. No products yet released to the market.
Advanced Systems Division -	Develops systems for market needs of the future in the general range of five years hence. Largely concerned with applications for existing devices, but also doing some product development.
Research Division -	Explores technology to develop radical new devices such as lasers, language translators, new materials. Concerned largely with applications of the more distant future in the range of 10 years hence.

Other organizations of IBM include two subsidiaries, the Service Bureau Corporation, which sells computation services, and the IBM World Trade Corporation which has 15 manufacturing plants in 13 countries, 40 card plants in 34 countries, 5 engineering laboratories, 196 service bureaus and 314 sales offices in 95 countries. The latter had a gross income of $653 million in 1962, up more than 30% from 1961.

Exhibit 3 - Competitive Computer Systems

"OFFICE AUTOMATION"® HANDBOOKS

The following is an example of the valuable information – not theory – contained in OFFICE AUTOMATION handbooks

COMPUTER COMPARISON CHART and CENSUS

COMMERCIAL DATA ON DIGITAL COMPUTERS USED IN BUSINESS APPLICATIONS

C - Magnetic Core
D - Magnetic Drum
Di - Magnetic Disk
DL - Delay Lines
K - Keyboard
MC - Magnetic Cards
MS - Magnetic Strip
MT - Magnetic Tape
PC - Punched Cards
Pr - Printer
PT - Punched Tape
VT - Vacuum Tube
MCR - Magnetic Character Reader
TF - Thin Film
OCR - Optical Character Reader

Manufacturer, Type, Model	Price Average System ($1,000)	Average Rental ($/Mo.)	Qty. Delivered	First Shipment	Deliv. Time (Months)	Input	Memory	Output	Approx. KVA Power	Average Working Area (Sq. ft.)
Punched Card Calculators and Computers										
IBM 604 (Model 1)	26	550	4,400	12-48	2-6	PC	VT	PC	7	25
IBM 607 (discon.)	42	900	540	10-53	2-6	PC	VT	PC	11	30
IBM 609 (Model A1)	55.5	1,175	100	11-60	14-16	PC	C	PC	1	20
Univac 60	75	1,015	1,000	6-54	3	PC-PT	VT	PC	10	50
Univac 120	97.5	1,350		6-54	3	PC-PT	VT	PC	10	50
Large-Scale Computers ($750,000 up)										
Burroughs B5000	790	18M	0	1962	16	K-PC-MT	C-D-MT	PC-MT-Pr	36	1,000
Control Data 1604	1,155	32M	16	1-60	10	K-PT-PC-MT	C-MT	PC-PT-MT-Pr	20	600
GE 210	800	16M	40	7-59	10	K-PC-PT-MT-MCR	C-Di-MT	PC-MT-PT-Pr	28	850
Honeywell 800	1,000	20-40M	18	11-60	12	PT-PC-MT-MCR	C-MT	PT-PC-MT-Pr	30	950
IBM 704 (discon.)	1,900	44M	100	12-55	-	PC-MT	C-D-MT	PC-MT-Pr-CRT	125	2,000
IBM 705 (Models I, II, III)	1,900	37M	155	11-55	15-20	PC-MT	C-D-MT	PC-MT-Pr	100	3,000
IBM 709	2,600	55M	50	8-58	15-20	PC-MT	C-D-MT	PC-MT-Pr-CRT	160	3,000
IBM 7070, 7072 and 7074	1,050	20-30M	90	3-60	18	PC-MT-MCR	C-Di-MT	PC-MT-Pr	32	1,200
IBM 7080	2,530	55M	0	1961	18-24	PC-MT	C-MT	PC-MT-Pr	45	1,000
IBM 7090	2,880	64M	80	11-59	16	PC-MT	C-MT	PC-MT-Pr	35	1,100
NCR 304	850	14M	16	1-60	12-15	K-PC-PT-MT-MCR	C-MT	PT-PC-MT-Pr	26	1,200
Philco 2000	1,600	36M	15	10-58	12	K-PC-MT-PT	C-D-MT	PC-MT-PT-Pr	24	1,200
RCA 501	800	16M	61	5-59	12	K-PC-MT-PT	C-MT	PC-MT-PT-Pr	35	1,200
RCA 601	2,000	35M	0	9-61	18	K-PC-MT-PT	C-MT	PC-MT-PT-Pr	40	1,200
Univac I (discon.)	1,280	23M	48	4-51	-	PC-MT	DL-MT	PC-MT-Pr	120	2,500
Univac II	1,520	28M	32	12-57	12	PC-MT-PT	C-MT	PC-MT-PT-Pr	120	2,500
Univac III	1,000	20M	0	1962	18-24	K-PC-MT	C-D-MT	PC-MT-Pr	52	1,200
Univac 490	1,500	30M	0	1962	18-24	K-PC-MT-PT	C-D-MT	MT-PC-PT-Pr	60	2,000
Univac 1101-1105	1,500	30M	45	5-50	12	K-PC-MT-PT	C-D-MT	PC-MT-PT-Pr	120	3,000
Univac 1107	2,500	50M	0	1962	18-24	K-PC-MT-PT	TF-C-D-MT	MT-PC-PT-Pr	93	2,500
Medium-Scale Computers ($75,000 - $750,000)										
Alwac III-E	120	3,600	40	2-54	1-3	K-PC-MT-PT	C-D-MT	PC-MT-PT-Pr	10	100
Bendix G-15	80	2,150	350	7-55	2	K-PC-MT-PT	D-MT-PT	PC-MT-PT-Pr	5	60
Bendix G-20	700	15,500	1	4-61	14.	K-PC-MT-PT	C-Di-MT	PC-MT-PT-Pr	20	600
Burroughs 205	260	4,600	150	1-54	4	K-PC-MT-PT	D-MT	PC-MT-PT-Pr	20	900
Burroughs 220	560	14,000	55	10-58	4	K-PC-MT-PT	C-MT	PC-MT-PT-Pr	30	1,200
Burroughs B251 VRC	217	3,975	0	1961	18	K-MCR-MS-PC	C	MS-Pr	15	500
Burroughs B270	300	7,000	0	1962	18	PC-MT-MCR	C-MT	MT-Pr	16	600
Control Data 160 and 160A	80	2,000	40	4-60	6	K-PC-MT-PT	C-MT	PC-MT-PT-Pr	1	60
GE 225	250	7,000	10	12-60	12	K-PC-PT-MT-MCR	C-D-Di-MT	PC-MT-PT-Pr	16	400
Honeywell 400	390	8,660	0	12-61	12	K-PT-PC-MT	C-MT	PT-PC-MT-Pr	23	600
IBM Ramac 305	190	3,200	900	11-57	12	PC-PT	Di-C-D	PC-Pr	15	360
IBM 650 (All types)	215-480	4-9,000	1,450	11-54	8-12	PC-MT-PT	C-D-Di-MT	PC-MT-Pr	20	100
IBM 1401 (All types)	150-400	3-10000	300	9-60	24	K-PT-PC-MT-MCR-OCR	C-Di	PC-MT-Pr	10	350
IBM 1410 (All types)	328-722	7-18,000	1	12-60	24	K-PC-PT-MT-MCR	C-Di-MT	PC-MT-Pr	26	400
IBM 1620	95	2,000	100	9-60	10	K-PC-PT	C	PC-PT-Pr	5	100
NCR 315	315-400	6-8,500	0	1-62	18	K-PC-MC-PT-MT-MCR	C	PC-MT-PT-Pr	15	700
NCR 390	75	1,850	2	5-60	12-18	K-PC-PT-MS	C	PC-PT-MS-Pr	3	200
Philco 2400	350	7,800	0	1962	12-18	K-PC-PT-MT	C	PC-MT-PT-Pr	12	250
RCA 301	271	5,800	5	7-61	12	K-PC-MT-PT-MCR	C-Di-MT	PC-MT-PT-Pr	10	400
Royal Precision RPC-4000	67	1,750	18	12-60	6	K-PT	D	PT-Pr	2	120
Royal Precision RPC-9000	120	2,450	1	8-60	6	K-PT-PC-MT	DL-MT	PT-MT-Pr	1	180
Univac File Computer 0 and 1	250-400	6-10,000	110	8-56	12	K-PC-MT-PT	C-D	PC-MT-PT-Pr	20	1,000
Univac Solid-State 80 and 90	168-360	4-9,000	300	10-58	12	PC-MT	D	PC-MT-Pr	15	300
Small-Scale Computers (Under $75,000)										
Burroughs E101	27	676	220	11-55	1-2	K-PT-PC	D	PT-Pr	2.6	25
Burroughs E103	29.7	985	20	9-60	3	K-PT-PC	D	PC-PT-Pr	2.5	25
Clary DE-60	18	540	25	2-60	1-3	K-PT-PC	D	PC-PT-Pr	.2	20
IBM 632	8.2	225	2,000	6-58	4-9	K-PC	C	PC-PT-Pr	1	15
Monroe Monrobot IX	9.6	276	125	3-58	2-3	K	D	PC-Pr	.8	15
Monroe Monrobot XI	24.5	700	20	4-60	6	K-PT-PC	D	PT-PC-Pr	1	20
Royal Precision LGP-30	49.5	1,100	460	9-56	1-2	K-PT-PC	D	PT-Pr	1.5	16

Where exact figures were not available, estimates were used.

Reprinted June 1961 from Office Automation Handbook

Published by Automation Consultants, Inc., 155 Fifth Avenue, New York 10, N.Y.

Publishers of Office Automation, Office Automation Applications, and Business Automation News Report

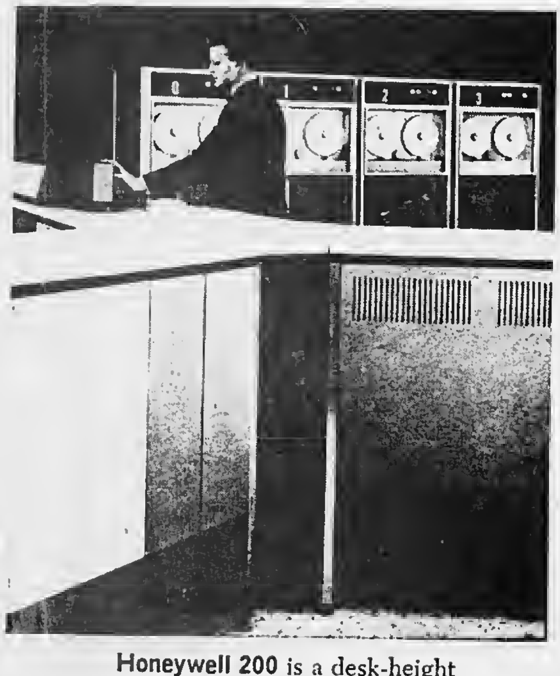
Exhibit 4 - Some Competitors of the Computer Industry

	Sales in Millions of Dollars				
	'58	'59	'60	'61	'62
Bendix	623.7	689.7	792.2	758.0	794.2
Burroughs	292.6	358.1	387.5	399.4	422.9
Control Data			9.7	19.8	41.0
IBM	1,171.8	1,309.8	1,436.1	1,694.3	1,925.2
Minneapolis Honeywell	328.5	381.4	426.2	470.1	595.9
N.C.R.	393.7	419.0	457.8	518.9	564.0
Ford Motor Company (Philco)	4,130.3	5,356.9	5,237.9	6,709.4	8,089.6
R.C.A.	1,170.7	1,388.4	1,486.2	1,537.9	1,742.7
Remington Rand	864.3	989.6	1,173.1	1,177.0	1,182.6
Royal McBee (Royal Precision)	94.9	104.0	111.1	106.8	106.3
Clary		10.8	10.2	9.0	8.3
Litton Industries (Monroe)	83.2	125.5	187.8	250.1	393.8
Smith Corona Marchant	87.1	90.4	93.4	96.5	103.2

New challenge to IBM

In a multimillion-dollar gamble, both Honeywell and GE are marketing new lines of computers that will compete directly in sales areas and costs with the industry leader

GE 425 is one of four star-shaped computers in Compatibles-400 family.



Honeywell 200 is a desk-height computer with silicon components.

Two major computer manufacturers—General Electric Co. and Minneapolis-Honeywell Regulator Co.—made major tactical moves this week to pry a larger share of the data processing market away from International Business Machines Corp.

Both companies announced they are bringing out lines of computers that compete directly with some of IBM's most successful equipment in market areas that IBM now dominates almost completely. It's a twist on the "if-you-can't-lick-'em-join-'em" approach and represents a multimillion-dollar gamble for Honeywell and GE.

Both companies believe this is the only route to survival in a murderously competitive business. Important to computer users, the moves bring significant cost reductions in broad areas of data processing equipment. But in this field, where IBM has set a blistering pace in developing sales, service, and customer education techniques, price alone is far from everything.

Direct aim. There is no doubt that the new Honeywell and GE computer systems will shake things up a bit. Honeywell's new computer, called the 200, is aimed directly at IBM's most successful machines—the 1440, 1401, and 1460 series that rent from about $2,000 to $16,000 a month. The best industry estimates put IBM installations and unfilled orders for this class of computers at more than 10,000 units, representing yearly rental income of about $400-million.

Honeywell's new 200 system, with rentals starting at $3,100 per month, is roughly in the same price range as IBM 1401 systems. But Honeywell claims the 200 computer is more than twice as fast. In a direct effort to lure IBM customers to its new machine, Honeywell is offering an accessory package it calls "Librator." This is a small device, plus a master computer program, that automatically translates programs prepared for IBM's 1401s to programs suitable for the Honeywell 200.

While attacking IBM on its strongest product front, Honeywell bowed to IBM's industry leadership by announcing a switch to a new ½-in. magnetic tape system that is compatible with IBM's equipment.

New GE family. While Honeywell is going after the small-to-medium class of computers, GE's Computer Dept. has decided to beef up its efforts in the next larger class of business data processing machines. GE announced a new family of four progressively larger and faster machines ranging in rental from $10,000 to $30,000 per month. It claims the new computers will do twice the work of "competing systems" in the same price range, or, conversely, will reduce hardware costs 50%.

The first two machines in the new GE family, called the 425 and 435, are specifically for business data processing jobs. Two larger computers are in the family, the 455 and 465, will also do engineering work.

GE will continue to produce its existing family of four general purpose computers in the 200 line. The 200 and 400 series computers cannot interchange programs, but they can be hooked together in a system with GE's Datanet communications processor so they can "talk" to each other. Programs and peripheral equipment such as tapes, card readers, and punches are the same within families so systems can be expanded without reprogramming or massive rewiring.

GE also confirmed that it was finishing up the design of a new series of large-scale scientific computers to be called the 600 family.

Frontal fight. The new products reveal that both Honeywell and GE have elected to compete with IBM across-the-board on product lines and price instead of trying to select areas IBM has overlooked or where its equipment is weak. "We can't see putting so much effort into just the parts of the market that are left over," says a Honeywell executive. "Besides, if they develop into significant business, IBM will come in strong eventually, so it's no more than a temporary strategy."

IBM marketing men watched the attack on their territory without much comment this week, though the industry was filled with rumors that IBM was ready to announce an extra large-scale computer.

The industry leader undoubtedly is preparing a counterpunch to Control Data Corp.'s successful invasion of the large-scale scientific computer market and probably will announce new large-scale systems early next year. Most in the industry also expect to see an IBM reaction to the GE and Honeywell computers in the form of new equipment soon.

ENGINEERING CASE LIBRARY

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INTERNATIONAL BUSINESS MACHINES CORPORATION (B)

Making the IBM 514 Card Punch Go Faster

An Engineering Case

While International Business Machines Corporation has cooperated with Stanford in encouraging the development of this course material and in supplying basic information and documentation, the company has not reviewed the course manuals and has had no part in their preparation and therefore does not necessarily concur with any opinions expressed or attest to factual accuracy. IBM wishes explicitly to avoid such intervention in order to allow complete editorial freedom to the University.

Prepared in the Design Division of the Mechanical Engineering Department, Stanford University, by Bernard Roth and Karl H. Vesper, as a basis for student projects with financial support from the National Science Foundation.

I.B.M. (B)

Making the 514 Card Punch Go Faster

Introduction

How to design automatic card punches to operate faster has been a subject of continuing concern to mechanical engineers at I.B.M. The most important advantage of automatic computer systems, high speed, is limited by the speed at which input-output units and other peripheral machines can operate. Nearly all large computer systems include card punching machines among their output units, often along with alternative output machines for magnetic tape, punched paper tape or direct display devices. The desirability of making faster punches is suggested by the fact that computer circuits can process enough information to fill 20,000 cards in less than one second, while the top speeds of card punching machines are described in hundreds of cards per minute.

The top speeds of card output units are generally limited by the mechanical speeds of their punching mechanisms. Thus, the mechanical punching mechanisms become the bottlenecks of output units which in turn can be the bottlenecks of computer systems, systems which can cost over $250.00 per hour to operate.

The punching mechanism of the I.B.M. 514 machine is used in several card processing machines, including the 721 machine which serves for a direct punch-out alternative in some computer systems, including the 7090 system at the Stanford Computation Center. In all its applications this punch mechanism limits the operating speed to 100 cards per minute. Consequently, the question of how to increase the speed of such a mechanism without sacrificing other necessary design objectives such as life, is one of concern to I.B.M. mechanical engineers.

The IBM 514

Duplication of punched card information, rather than direct output for a computer is the purpose of the 514 machine itself although its punching mechanism is used in direct punchout machines as well. The 514 will automatically punch the information in the same or a different arrangements on another set of cards.

Cards to be read are set in one hopper of the machine and cards to be punched are set in another hopper. Both stacks of cards feed at the same time, each through a different part of the machine. The machine stops automatically if either of the two input hoppers becomes empty or if either of the two output hoppers becomes full. Each hopper can hold 800 cards.

One end of the 514 contains the read section and the other contains the punch section. Each of these sections has its own feed mechanism. The arrangement of these sections in the overall machine can be seen from the pictures appearing in Exhibits 1 and 2. A schematic diagram of how cards flow through the machine appears as Exhibit 3. For all operations the cards are placed in the hopper face down and move sideways, that is, in a direction perpendicular to the long edge of the card. Each of the twelve rows is then read or punched one row at a time. Any number of the 80 punches per row can punch at once. The speed of the machine, 100 cards per minute, is the same regardless how many holes are punched per card.

The 514 sells for $4,400. - 4,800. depending on accessories, or rents for $70. - 125. per month including maintenance by I.B.M. The price of the punch section, if bought separately from the overall 514 machine, is $2496.00 , F.O.B. Rochester, Minnesota.[1] Maintenance for a purchased machine can also be bought from I.B.M., the cost being $16.50 - 25.25 per month for a machine up to 36 months old, $22.00 to 34.00 for one 36 to 72 months old and $27.75 to 42.50 for one older than 72 months. All parts required are included in the maintenance charge. An I.B.M. "Customer Engineer" will visit and provide maintenance on whatever schedule is deemed appropriate.

One I.B.M. Customer Engineer commented: "How often you have to service the machine depends on how steadily it is used. Some users duplicate cards rather infrequently, whereas others keep their machines running almost steadily, day and night. For normal eight hour per day usage, servicing about once a month has generally been about typical in my experience.

"The maintenance required normally involves some cleaning, lubrication and minor adjustments. Sometimes reading brushes need replacing after a damaged or worn card has been run into the machine, jammed and been pulled out backwards against the brushes by the operator.

"A continuing cause of wear in the machines seems to be "card dust," a fine, almost gritty powder that comes from the punching operation. The dush itself is quite abrasive and can wear feed rolls and other moving parts. It also seems to dry out the lubricants of the machine.

"Wear is always a problem with these machines. The parts contacting the cards, such as stacker shoes which feed out finished cards, and the die plates for the punches usually have to be replaced most often. It, of course, depends on the amount of usage. If the machine is running continuously straight through three shifts a day, as some customers use it, replacement of parts may be required in the first year, and the overall machine may last only three or four years. With more normal operation, on the other hand, it will last proportionately longer."

---

1 The three main elements of the punching section covered by this price are the Feed Unit Assy. (Part No. 601703) $1,140., the Magnet Unit Assy. (Part No. 122583) $972., and the Punch Die and Stripper Assy. (Part No. 208598) $384.

Punch Section of the 514

The punch section can be considered as two main parts (1) the punch feed rolls and (2) the punch. The feed rolls are arranged in pairs, each pair having one roll above and one below the card pressing together on the card. A geneva mechanism drives the feed rolls incrementally so that the card stops intermittently while it is punched then advances a step to punch again.

The punch consists of an aggregate of 80 separate punch prongs which mate into a fixed die with 80 holes spaced as the 80 lines along a card. A common punch bail driven by an eccentric continuously reciprocates. For each punch there is an interposer moved by a magnet opposing a spring. When the interposer is pushed by the magnet between the bail and a punch, it fills the space between the two and that punch is pushed by the bail through the card and into the die.

Operation of the punch and its drive is described in more detail in Appendix I which also contains pictures and exploded-view drawings of the mechanisms. In Appendix II are data on electrical circuits and timing.

Problems of Speed

The punch could be speeded up simply by putting a larger pulley on the drive motor. But doing so had been found to cause the following problems:

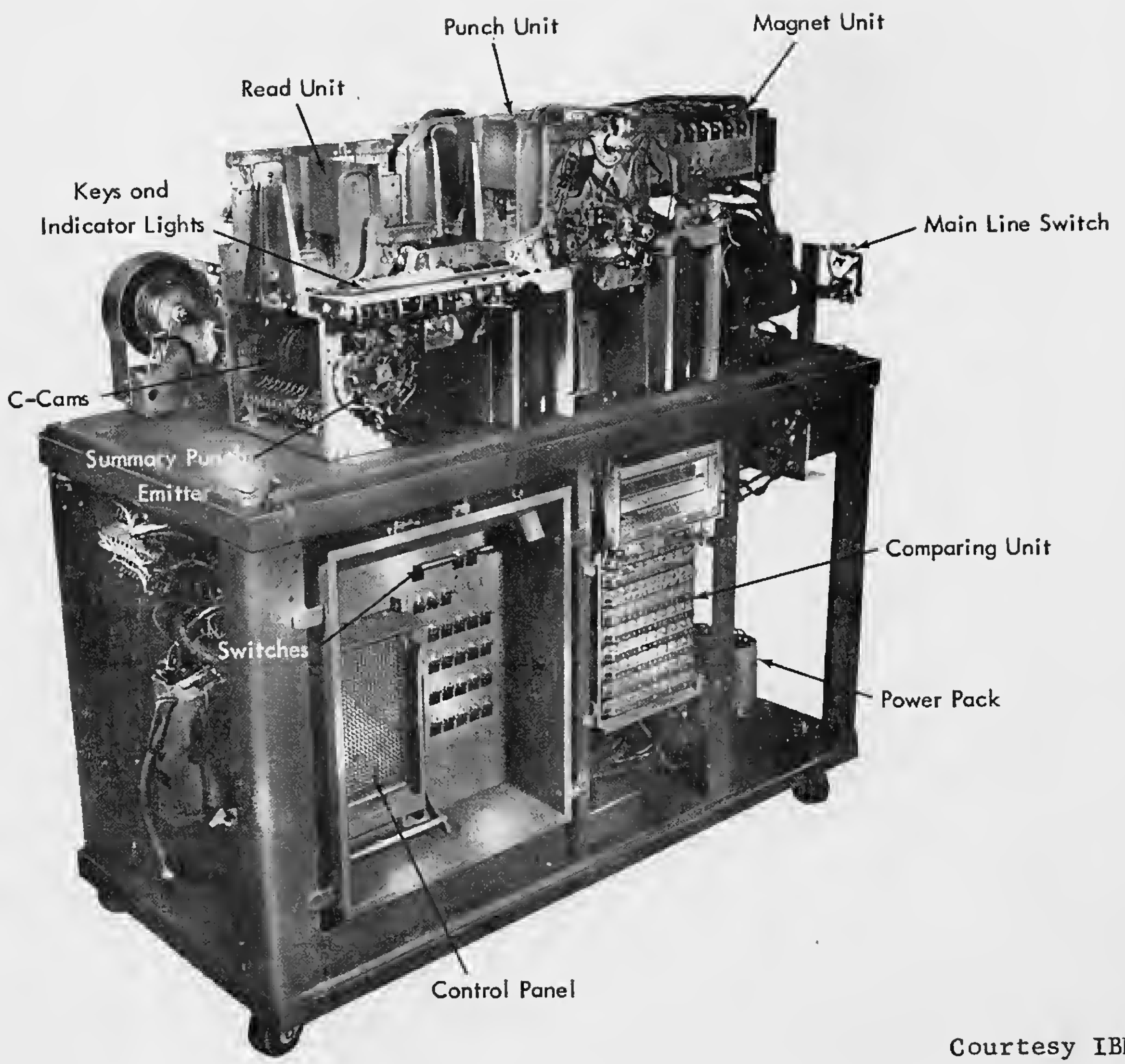
1. Wear - machines were designed according to one IBM engineer, to operate for at least 5 or 6 years without mechanical failure. Another design objective was that all wearing parts should last approximately the same length of time. With increased speed, however, it had been found that the feed roll drive mechanisms wore out first and in less than the design life.

2. Punch skip - The speed of the machine could not be increased an order of magnitude without the dependability of the interposers becoming unacceptably low. The difficulty was that the magnets would not pull the interposers fast enough to actuate the punches. It had been determined impractical to increase power to the magnet substantially because heat generation would thereby become too high.

3. Card slip - As speed increased, the feed rolls had to accelerate cards from station to station at correspondingly higher rates. Depending upon a number of factors such as the adjustment of the machine, condition of the cards, etc., the cards might slip in the feed rolls at higher speeds which caused inaccurate punching of the holes. By keeping the operating speed down to that at which the machine was rated, however, acceptable accuracy could be dependably maintained.

In Appendix III are excerpts from the maintenance manual describing care and adjustments of the punching section. Dimensions and materials of the main parts of the punch and drive mechanism along with data on the magnets appear in Appendix IV.

Exhibit 1 - Front View of the IBM 514



Courtesy IBM

Exhibit 2 - Rear View of the IBM 514

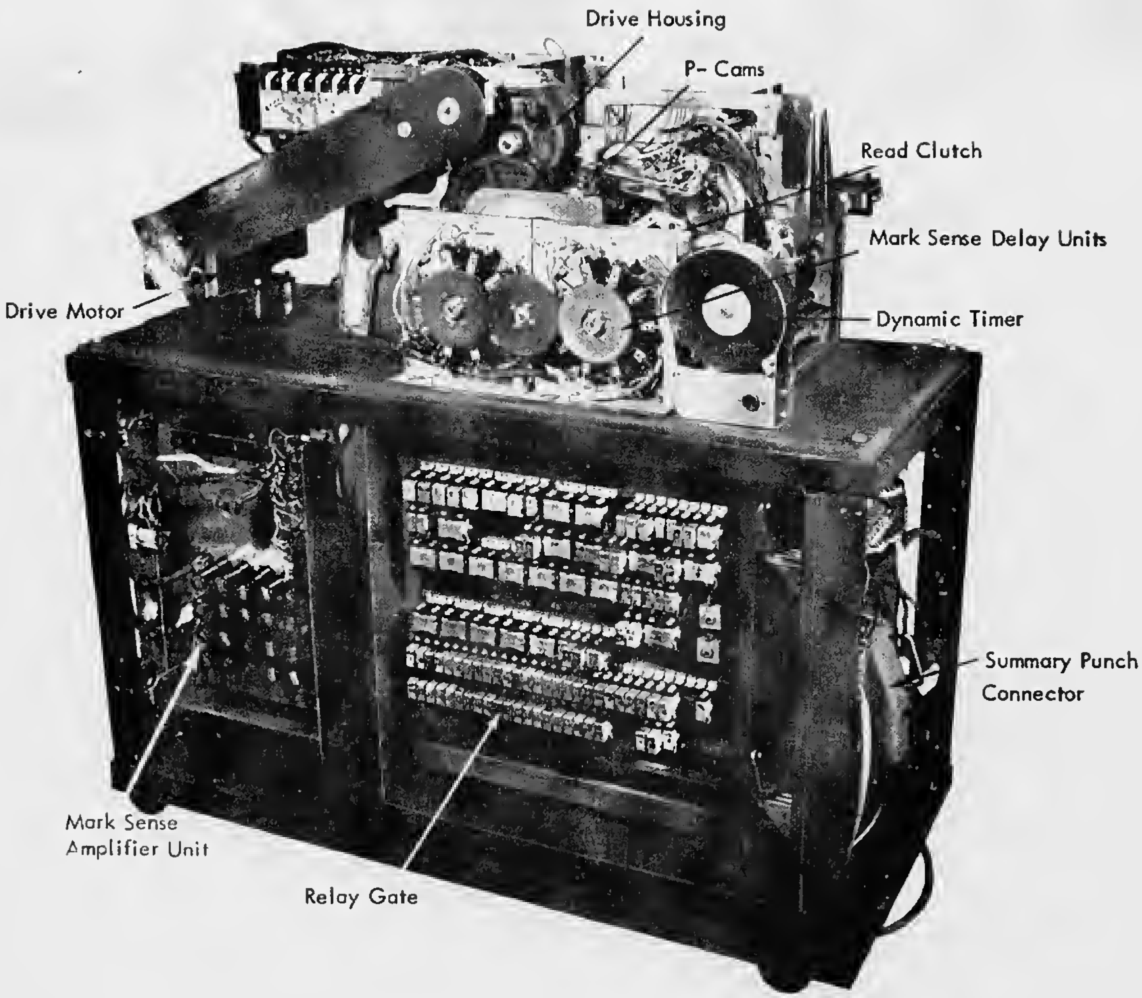
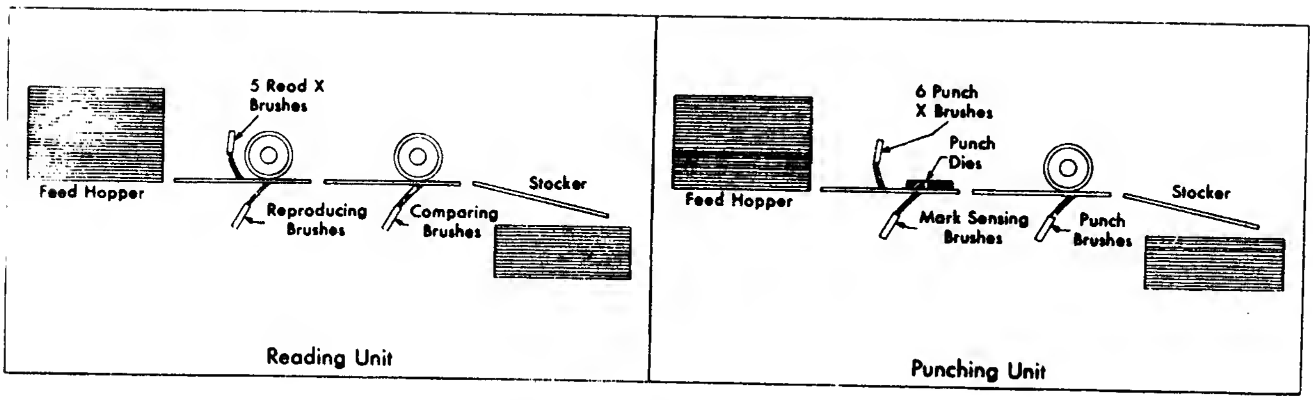


Exhibit 3 - Schematic of Flow of Cards in the IBM 514



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APPENDIX I

Mechanical Principles of the IBM 514 Punch

This text describes, with references to the attached figures following it, mechanical operation of the punching section of the 514 machine. Figure 1 shows schematically the layout of feed and punch mechanisms in the machine. Figure 2 shows the drive mechanism for the punching section.

Drive Mechanism

Power to drive both the punch and the read units of the machine is furnished by the drive motor. The drive motor transmits power to a gear housing through a V-belt and pulley. Because either feed may at times operate independently, there are two clutches to provide for independent operation of the read and punch units. These clutches, the punch clutch and the read clutch, are of the pawl and one-tooth ratchet type. The one-tooth ratchet of each clutch is driven by a train of gears from the drive housing, which operates continuously as long as the drive motor is running. The pulley turns the pulley shaft, to which are attached two gears. The gear toward the front of the machine drives the twin eccentric shaft. The gear toward the rear of the machine drives a large gear to the right of itself (facing rear of machine). This gear (the punch clutch idler gear) transmits motion to all other continuously running parts, the punch clutch one-tooth ratchet, the read clutch one-tooth ratchet and the C-cam shaft.

The index drive gear, the small spur gear outside the drive housing, is pinned to the same shaft as the punch clutch idler gear and, therefore, turns with the idler gear. The index drive gear drives the large index gear. The hub of the index gear serves as the one-tooth ratchet for the punch clutch.

Attached to the index gear (punch clutch gear) by three studs is another smaller gear. This gear drives a train of gears, which in turn operate the read clutch one-tooth ratchet gear. The P-cam contact drive gear is pinned to the index gear shaft, and drives a train of gears that operate the P-cams. The R-cams turn when the read clutch is engaged and are driven by the gear to which the read clutch pawl arm is attached.

When both clutches are disengaged, only the eccentric shaft, the punch and read clutch one-tooth ratchets, and the C-cams turn.

Source: Adapted with IBM permission from "Customer Engineering Manual of Instruction 514, 519, 528 Reproducing Punches."

If the punch clutch is engaged and the machine is started, the feed knives, the first, second, and third pairs of feed rolls, the punch brush contact roll and the stacker roll in the punch unit operate. Also the second and third sets of feed rolls, the comparing contact roll, and the stacker roll of the read unit operate under the control of the punch clutch. The two pairs of feed rolls in the read unit turn smoothly while all the rolls in the punch unit turn intermittently. The intermittent movement is necessary to have the card stopped in punching position. The P-cam contact unit also operates under the control of the punch clutch.

If the read clutch is engaged and the machine is started, the feed knives, the first pair of feed rolls, and the reproducing contact roll in the read unit operate. Also, the R-contact cams operate under the control of the read clutch.

PRINCIPLE OF PUNCHING

As shown in Figure 3, there are 12 punching positions on the card.

The distance between any two of the twelve punching positions is 1/4" and is called a cycle point. Therefore, for each cycle point the card has moved 1/4" on its path through the machine. The card, being 3-1/4" wide, covers 13 cycle points and in the feed there is 1/4" between each card and the next one. Therefore, the distance from the leading edge of one card to the leading edge of the following card is 3-1/2". Because each 1/4" equals a cycle point, each cycle of the reproducer is comprised of fourteen cycle points, and the machine index is divided into 14 divisions; therefore, this machine is known as a fourteen-point-cycle machine.

Figure 4 shows the part the eccentric shaft plays in the punching operation. The circular motion of the gears and shaft is transformed into reciprocating (up and down) motion by the eccentric shaft which revolves at 1400 rpm. This motion is imparted to the punch bail through the punch bail eccentric links. As shown in Figure 4A, when the magnet is de-energized, the punch bail may move up and down without contacting the interposer; therefore, no punching takes place. When the punch magnet is energized (Figure 4B), the armature is attracted, and through the magnet pull wire, pulls the punch interposer into engagement with the punch bail tongue. Because the bail tongue operates up and down, it carries the punch interposer and the punch connected to it down through the card. On the return stroke, the punch is positively withdrawn from the card by the upward motion of the punch bail. As the interposer approaches its upward limit of travel, it contacts the knockoff bar, which cams it away from the punch bail tongue.

Eighty punches are arranged in a row, each with its individual interposer and magnet. There is but one punch bail, which spans the eighty punches. The punch bail operates up and down once for every punching

position of a cycle. Any interposers that are pulled into engagement with the punch bail tongue will cause their respective punches to be driven down through the card. Thus, if eighty magnets are impulsed, all eighty interposers will be engaged with the punch bail, and eighty holes will be punched.

GENEVA MECHANISM

While the punches are being driven through the card and withdrawn, the card must not be in motion. If the card were in motion, the holes would not be clean-cut, but ragged and torn. Because the card must be stationary while it is being punched, and must then be moved to a new punching position fourteen times each cycle, the motion of the card must be intermittent. This intermittent motion is obtained by means of a geneva mechanism.

The geneva drive gear is located just inside the gear housing and pinned to the pulley shaft. It also drives the gear train which drives the CR cams and feed clutch one-tooth ratchets. A stud and roller fastened to this gear operate in the slots of the driven member of the geneva gear (the geneva disc, Figure 5).

The hub of the geneva drive gear is a cam surface for about two-thirds of its periphery. This cam surface holds the feed rolls in a stationary position during puching time (Figure 5).

The geneva disc has seven deep slots and seven shallow cuts in it. The roller of the drive gear operates in the deep cuts in the geneva disc, and the cam surface rides in the shallow cuts. As the drive roller leaves the deep cut of the geneva disc, the cam surface turns into the low cut, thus stopping the geneva disc from turning, and holding it still until the drive gear has rotated to a point where the drive roller enters the next deep slot of the geneva disc and starts driving. Then the cam surface has turned to a point where it releases the disc and allows it to turn freely. The geneva disc turns continuously as long as the drive motor runs. However, no motion is transmitted to the feed rolls until the geneva pawl is engaged with its one-tooth ratchet gear. The one-tooth ratchet gear is meshed with the feed roll drive gears. The geneva pawl and the geneva disc are pinned to the same shaft, which runs through the hub of the one-tooth ratchet. The one-tooth ratchet is free on the shaft and does not turn unless the geneva pawl is engaged (Figures 6 and 7).

When the punch clutch is not engaged, the geneva pawl rides on the surface of the one-tooth ratchet during the greater part of the cycle. When the pawl reaches a point opposite the single tooth, the tail of the pawl strikes the pawl disengaging roller and is cammed away from the ratchet until it has moved past the point where it may engage in the single tooth of the ratchet. From the foregoing, it is evident that the operation of the geneva pawl is controlled by the pawl disengaging roller. The pawl disengaging roller is mounted on a triangular plate that is free to pivot on the latch cam roller arm. The latch cam roller arm is

operated by the latch cams, which turn only when the punch clutch is engaged. When the punch clutch is engaged, the latch cams turn, causing the latch cam arm to rotate in a counterclockwise direction. As the latch cam arm rotates, the upper end moves to the left and down, allowing the pawl disengaging roller to move past the single-revolution timing cam, and thus allowing the ganeva pawl to engage in the one-tooth ratchet. Near the end of the machine cycle, the latch cam causes the latch cam arm to rotate in a clock wise direction, carrying the pawl disengaging roller to the right. The roller strikes the tail of the geneva pawl and disengages the pawl from the one-tooth ratchet when the roller is backed by the single-revolution timing cam.

Single-Revolution Timing Cam

Because the geneva disc has 7 cuts in it and moves the card one cycle point for each cut and the machine is a 14-point-cycle machine, the geneva disc must make two revolutions per machine cycle. Therefore, the ganeva pawl will pass the pawl disengaging roller twice during each cycle. The purpose of the single-revolution timing cam is precautionary. At the end of the first revolution of the geneva dog and intermittent disc, the flat side of the single-revolution timing cam should be down (Figure 8). The pawl disengaging roller is free to swing away from the tail of the pawl. This assures that the pawl will not be disengaged by the pawl disangaging roller until the punch unit mechanism has reached its proper latching position. If it were possible for the geneva pawl to disengage halfway through the cycle, the cards in the feed would be out of synchronism with the machine index.

FEED KNIVES

The feed knives are designed to feed one card into the throat at a time by a reciprocating motion. They are carried back and forth by a gear sector that meshes into the feed knife rack. The gear sector is pinned to a shaft that oscillates under the control of a cam and followar. Figure 9 shows the punch feed knife drive, and Figure 10 shows the read feed knife drive.

CLUTCHES

Both the punch clutch and the read clutch are of the one-tooth ratchet type (Figure 11).

The principal parts of the clutch are a continuously running one-tooth ratchet, a clutch pawl, a latching mechanism composed of a clutch latch arm and keeper, and a magnet. The magnet provides a means of electrically controlling the operation of the clutch. The clutch magnet armature serves as tha latching mechanism. When the magnet is energized, the armature is attracted and allows the pawl to pivot in a clockwise direction by spring tension. The pawl drops into the continuously running one-tooth ratchet and turns with it. The pawl rotates about a stud on the clutch pawl arm, and the clutch pawl arm is pinned

to a shaft; thus, when the pawl turns, the shaft to which the pawl arm is pinned must also turn.

Because there is but one latching point, if the clutch latch is tripped, the pawl must make one complete revolution before it can be relatched. As the pawl reaches the end of the cycle, if the clutch magnet is de-energized, the armature will be pulled by spring tension to a point where its latching surface will engage the tail of the pawl and cam it out of the one-tooth ratchet. As the pawl is cammed out of the one-tooth ratchet, the keeper gets behind the clutch pawl arm. This prevents the shaft, to which the clutch pawl arm is attached, from turning backward. If the shaft were to turn backward, the pawl would drop against the one-tooth ratchet and nip. Note that as the shaft revolves, the keeper does not get behind the clutch pawl arm, and that every time the one-tooth ratchet comes around, the pawl catches in it, moves slightly, then is disengaged by the latch. This condition has a tendency to round off the edge of the one-tooth ratchet, as a result of which the pawl may pull out of the ratchet part way through a cycle and cause the mechanism operated by the clutch to lose a cycle. When operating under power, the momentum of the mechanism will normally allow the keeper to get beneath the clutch pawl arm.

OIL PUMP

The oil pump is a simple rotary-vane type pump. It is located inside the drive housing and is driven by the shaft of the index drive gear (Figure 12). It pumps oil from the bottom of the drive housing to the top where it is free to run down over the geneva and gears.

The rotor is pivoted off-center in the housing as shown in Figure 13. The expansion chamber at the inlet provides a vacuum and causes the oil to enter the pump from the well below. The compression chamber at the outlet causes oil to be forced out at the top.

CONTACT CAMS

The C-cams are located in the read unit just below the read magazine. There are four C-cams, 11, 12, 13, and 14, which supply timed impulses for each of the 12 punching positions of the card. The other C-cams, mounted on the C-cam shaft, supply timed machine impulses for various functions in the machine. The C-cam shaft rotates whenever the motor is running. The cams are numbered from front to back on the machine.

R-Cams

The R-cams and contacts are located on the left rear of the machine and supply timed machine impulses only when the read clutch is engaged. They are numbered from front to back.

P-Cams

The P-cams and contacts are located directly above the R-cams and supply timed impulses when the punch clutch is engaged. They are numbered from front to back.

COMPARING UNIT

The comparing unit is located on the lower front right side of the machine. It consists of 80 magnets, which control individual pawls. The magnets are the two-coil bucking type, which will cause a pawl to trip if a circuit is complete to one coil only. A circuit to both coils simultaneously will have a neutralizing effect and will not trip a pawl.

A tripped pawl will cause a bail to unlatch, which will in turn operate a transfer contact. This contact serves two functions; namely, to open the circuit controlling the feed clutches and also to complete a circuit to the comparing signal light. The light is an indication to the operator that the cards do not agree. The pawl or pawls that are tripped remain in a tripped position and indicate to the operator the exact positions in the comparing unit that did not agree. The indicator in this unit represents the comparing magnet being used. The control panel must be checked to determine which column in the card is wired to that comparing magnet.

It is necessary to manually relatch the tripped bail. The bail in turn relatches the pawls that may have been tripped and restores the comparing contact to normal.

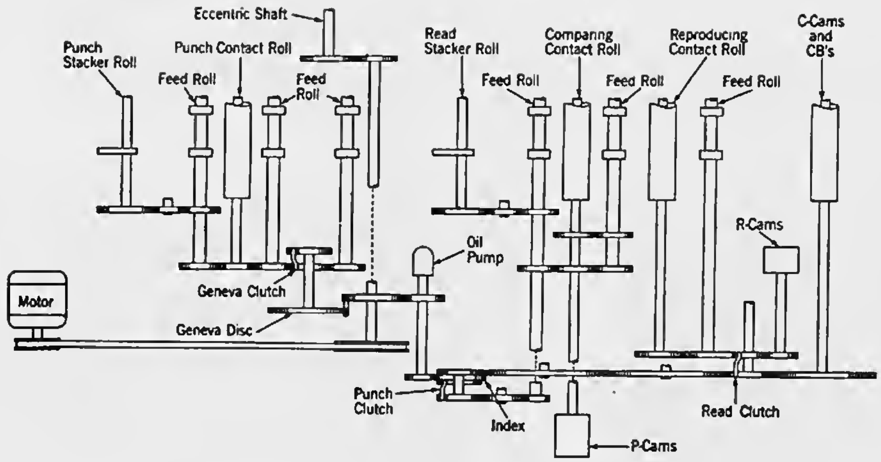


Figure 1 Schematic of Clutch Control of Feed Rolls

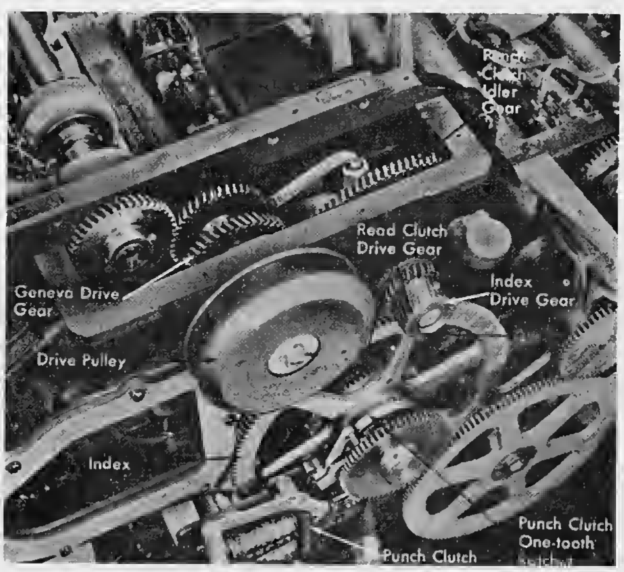


Figure 2 Drive Mechanism

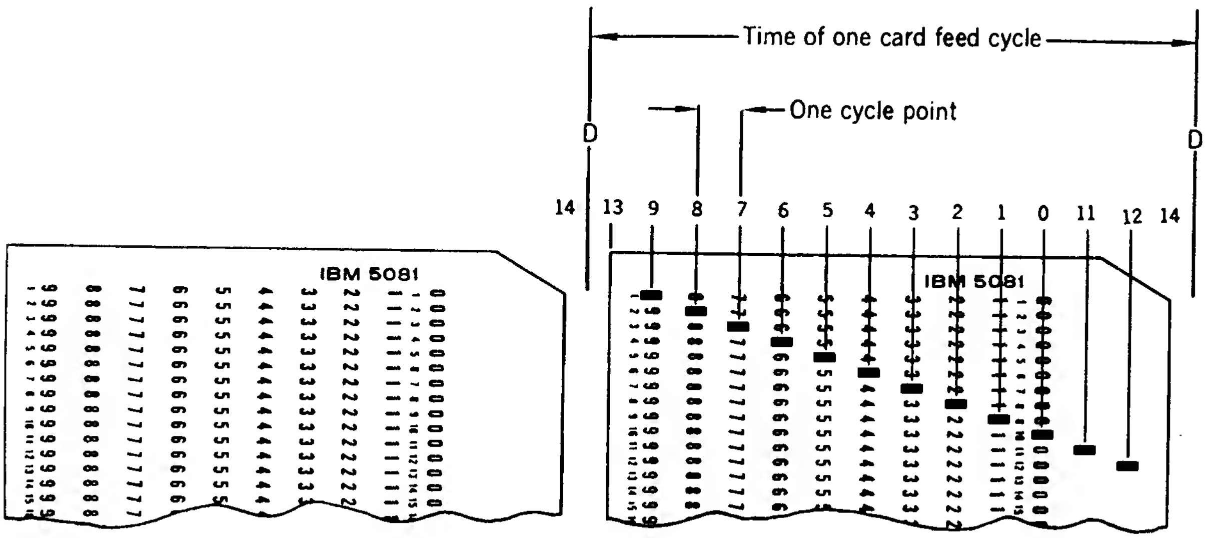


Figure 3 Card-Feed Cycle

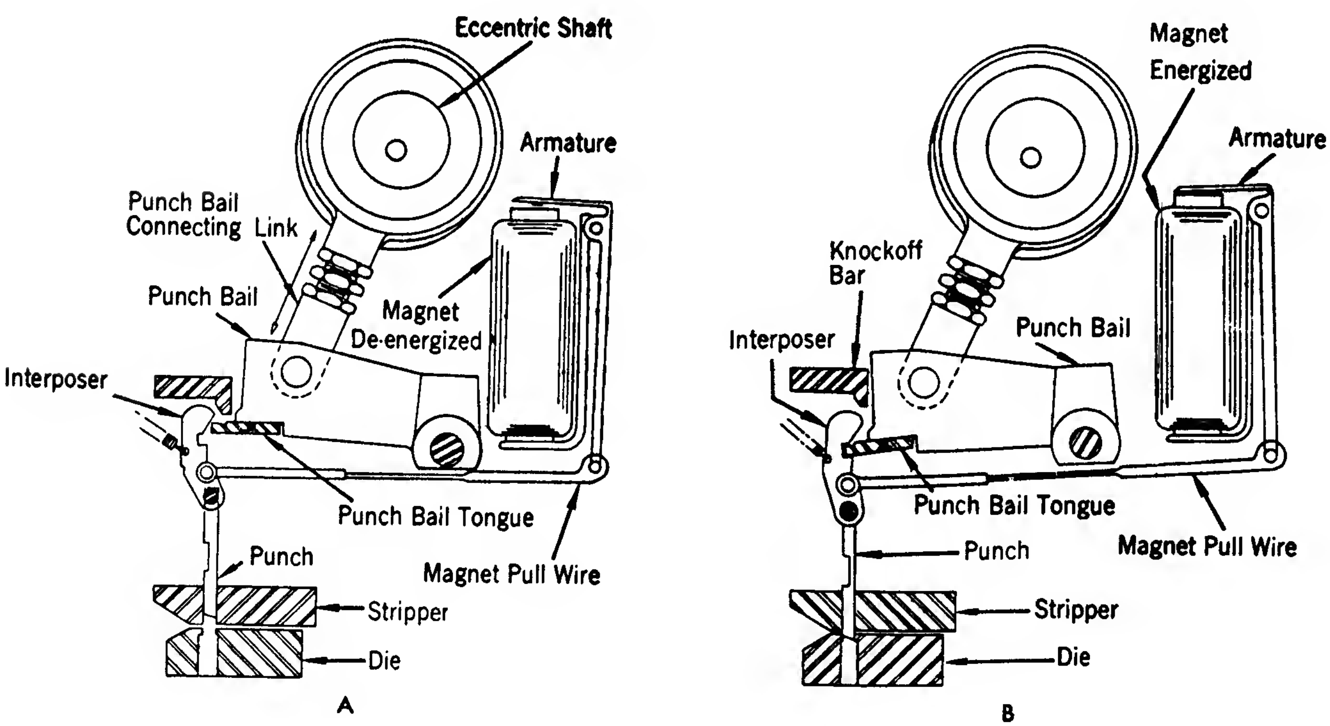


Figure 4 Principle of Punching

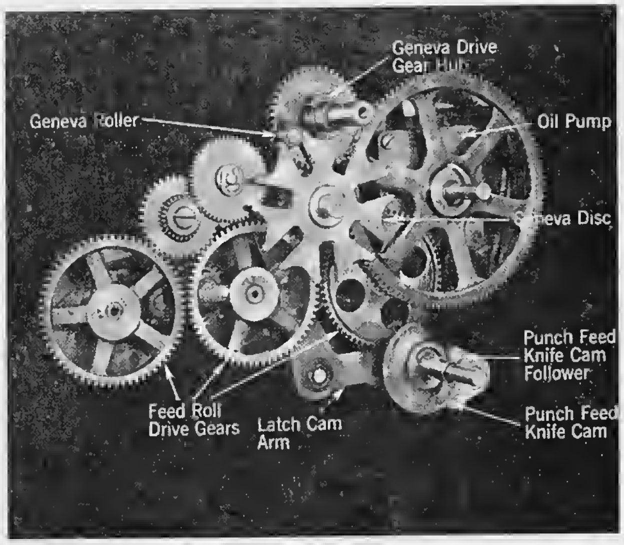


Figure 5 Geneva Mechanism

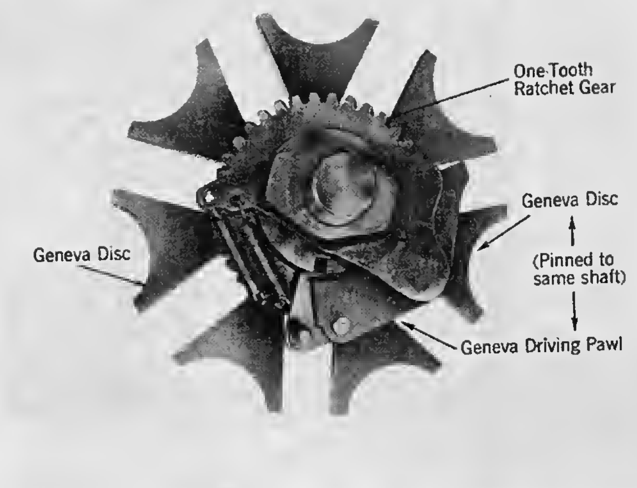


Figure 6 Geneva Pawl and Ratchet

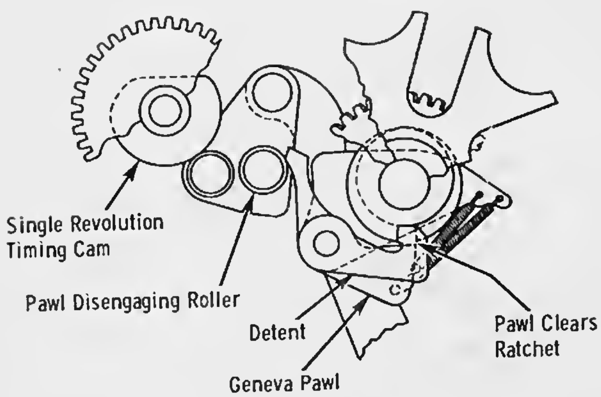


Figure 7 Pawl Disengaging Roller

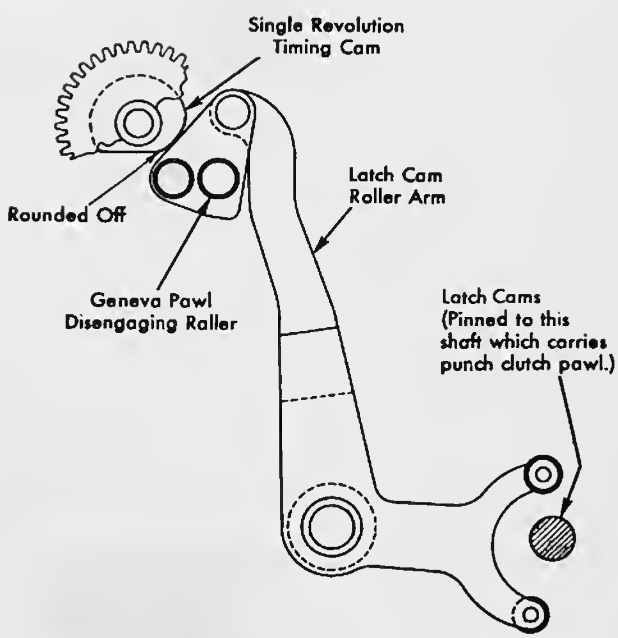


Figure 8 Single-Revolution Timing Cam

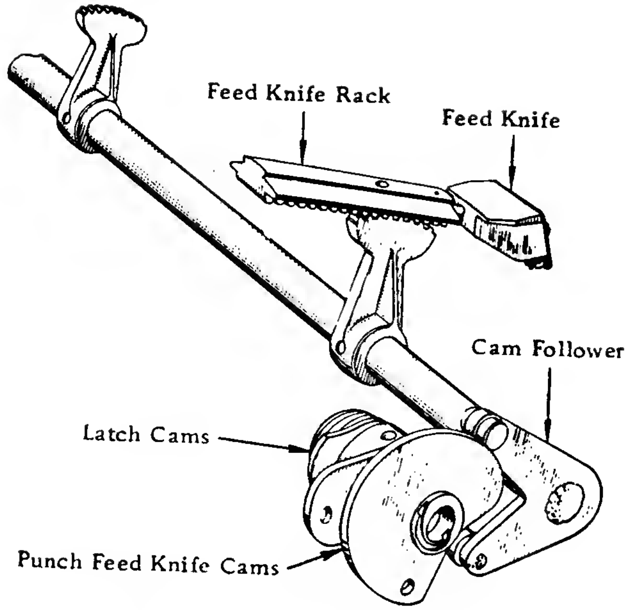


Figure 9 Punch Feed Knife Drive

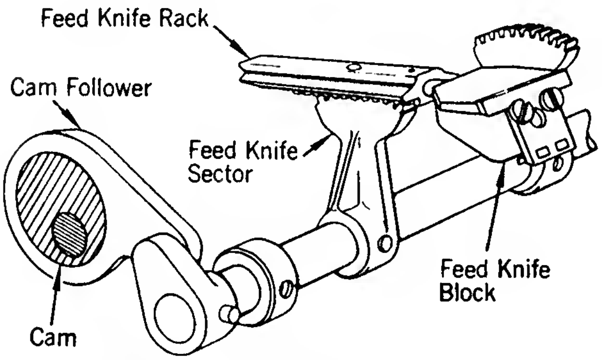


Figure 10 Read Feed Knife Drive

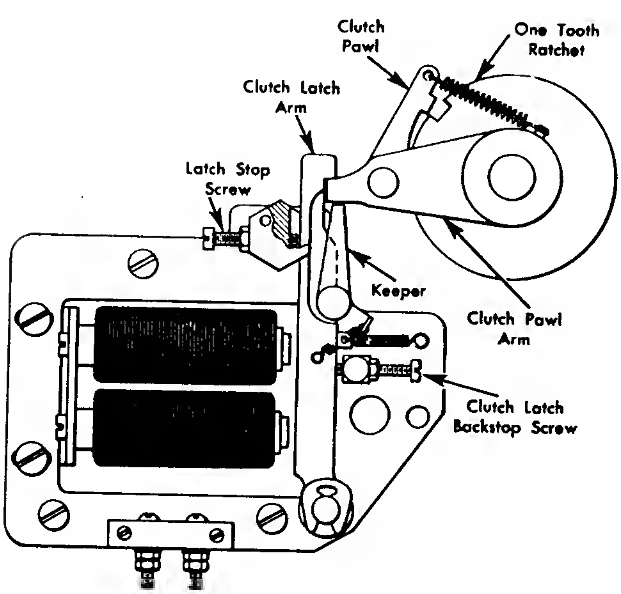


Figure 11 Clutch

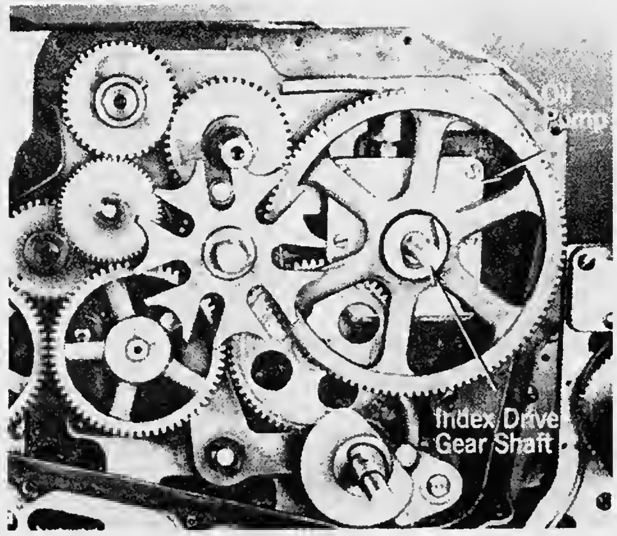


Figure 12 Oil Pump Mounted

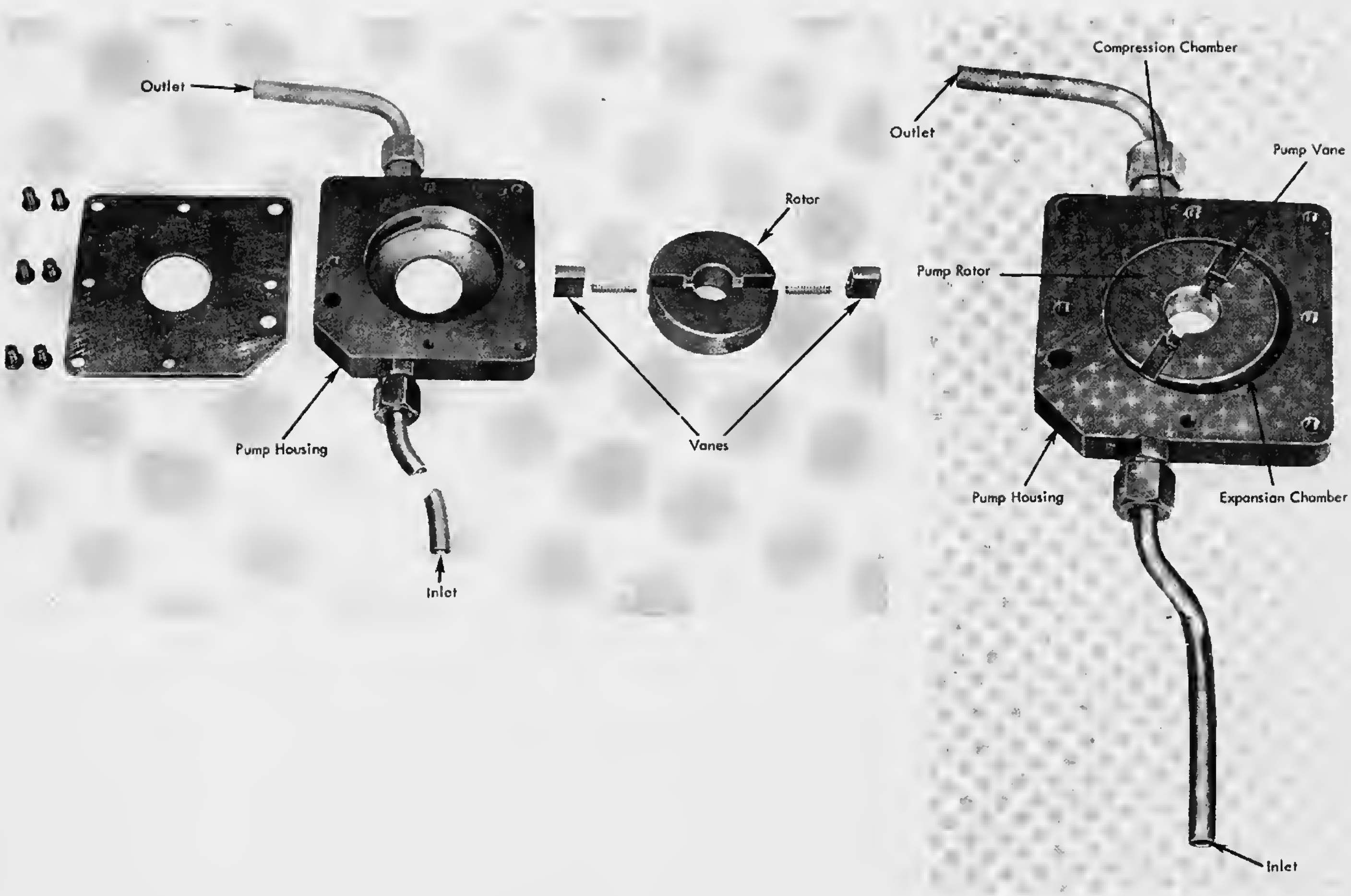


Figure 13 Oil Pump Dismantled

I.B.M. (B)

APPENDIX II

Electric Circuits, and Timing

514 REPRODUCING PUNCH

WIRING DIAGRAM 223601-P

THE GENERAL layout of the wiring diagram should be studied before a study of specific circuits is begun. The general layout of the diagram is as follows:

Section 1, 2, 3	Power supply, clutch, and card lever circuits.
Section 4	Start and run and X-brush control circuits.
Section 5	X-Brush control and summary-punch circuits.
Section 6	Summary-punch and selector circuits.
Section 7-8	Brush, reading, comparing, and punch magnet circuits.
Section 9-10	Location charts.
Section 11-12	Electrical and mechanical timing charts.

The circuits in this book will be in circuit outline form except where it is felt that a point-to-point description is advisable. The circuits will be preceded in each case by the objective of the circuit and any general comments necessary.

POWER SUPPLY

IN SECTIONS 1, 2, 3, 4 of the wiring diagram are found the power supplies and drive motor connections for all normal line voltages. However, for instructional purposes, only two of these circuits will be considered in this book. The first will be the 115v-230v single-phase ac supply using a motor and generator set to supply 40 volts dc to the machine. The second will be the 115v-230v single-phase ac supply using a transformer and selenium rectifier to supply 40 volts dc to the machine.

In all of the motors shown in these two circuits, a normally closed contact is shown. This contact is a centrifugal switch, which gives the motor a higher starting torque, then opens to let the motor run normally. The switch is a part of the motor and is located inside the motor housing.

115v-230v 1 Phase Using Motor and Generator

OBJECTIVE: To supply 40 volts dc to machine circuits and supply 110 volts ac to drive motor.

A. Motor and Generator Set

1. The main-line switch applies 110v ac directly to the motoe of the motor generator set.
2. The motnr drives the generator, and the voltage control resistoe is adjusted to provide 46 volts' ± 1 volt output between 40v-1 and 40v-3.

B. Drive Motor

1. The drive motor is connected directly to one side of the line through the main-line switch.
2. The other side of the motor is connected to the other side of the line through heavy-duty relay points and long time lag fuse 6.

115v-230v 1 Phase Using a Transformer and Rectifier

A selenium rectifier has the characteristic of having a high resistance to the flow of current in one direction and a relativaly low resistance to the flow of current in the other direction. Electrons will be able to flow in a direction opposite to the direction of the arrowhead in the rectifier symbol.

OBJECTIVE: To supply 40 volts dc to machine circuits.

1. The main-line switch applies 110 volts ac directly to the primary side of the transformer.
2. The secondary side of the transformer is connected to the full-wave selenium rectifier, which supplies 46 volts ± 2 volts to 40v-1 and 40v-3 under no load conditions. The point-to-point ciecuits are given in the direction of electron flow for the two half cycles of an ac cycle.
   a. When the top of the secondary is minus:
      Top of the secondary, selenium rectifier, to minus side of selenium rectifier, post 40v-1, through some machine circuit to post 40v-3, to plus side of selenium rectifier, to bottom of selenium rectifier to the bottom of the secondary winding of the transformer.
   b. When the top of the secondary is plus:
      Bottom of the secondary, selenium rectifier, to minus side of rectifier, post 40v-1, through some machine circuit to post 40v-3, to plus side of selenium rectifier, to top of selenium rectifier, to the top of the transfoemer secondary winding.

Source: Copied with IBM permission from "Customer Engineering Manual of Instruction 514 519 528 Reproducing Punches."

REPRODUCING

A REPRODUCING operation requires the use of both feeds with the original cards placed in the read feed and the blank cards in the punch feed. The columns to be reproduced are wired from the read brushes of the columns to be read to the punch magnets of the columns to be punched. The switch settings for this operation would normally be: reproduce switch ON, detail or master switch set to MASTER, and all other switches OFF.

With cards placed in machine as described, the start key will be closed to feed cards into the machine. The cards will operate card lever contacts at the various card stations in the machine. The card lever contacts and the relays associated with them provide for continuous operation of the machine as long as cards are feeding. They also provide for controlling the circuits to the contact rolls so that they are hot only when cards are at the respective contact roll positions, and further, these card lever contacts provide for interlocking the two feed units so that they will remain in step with each other. Function charts showing the three cycles necessary for continuous operation are seen in Figure 59.

Start and Run Circuits

OBJECTIVE: To provide a run circuit by establishing a continuous hold for R10, which controls the HD1 relay and feed circuits.

A. First Cycle (First depression of start key) Figure 60

1. R3 energized by punch magazine CLC. 3B
2. R6 energized by read magazine CLC. 3B
3. R13 energized by start key through 6-2 N/O and 3-2 N/O. 4B
4. 13-1 holds R13 back to 40v-5 through stacker switches, stop switch, etc. 4B
5. R10 picked by 13-3. 4B
6. R10 holds through R5 and P6. 4B
7. HD1 and R9 energized by 10-5 and 10-6 N/O. 3B
8. Drive motor energized by HD1 points. 1B
9. Punch clutch energized by C1, controlled by 1-1 and 4-1. 2B
10. Read clutch energized by C2, controlled by 1-1 and 4-1. 2B
11. R4 energized by Read CLC1. 3B
12. R1 energized by Die CLC. 3B
13. Read CLC2 will close this cycle if corner of card is not cut. 7B

B. Second Cycle (Second depression of start key) Figure 61
Steps 1-13 are the same as cycle one.

14. Read CLC2 will close this cycle if it was not closed on the previous cycle. 7B
15. R7 may be energized during this cycle depending on the corner cut. However, it will be too late to establish a hold for R10, because P6 will have previously de-energized R10. 6B

C. Third Cycle (Third depression of start key) Figure 62

The starting of the machine is the same as cycle one and two. However, a continuous hold for R10 will be established during this cycle as soon as R10 and R7 are both energized. This circuit is as follows: 40v-5, knockoff contact, die contact, auxiliary start key jack N/C contact, I17, I18, comparing contact left, 13-2 N/O, 4-3 N/O, 6-3 N/O, 8-2 N/C, 7-1 N/O, 22-3 N/C, 1-2 N/O, 3-3 N/O, 10-1 N/O, R10 hold coil, fuse 2.

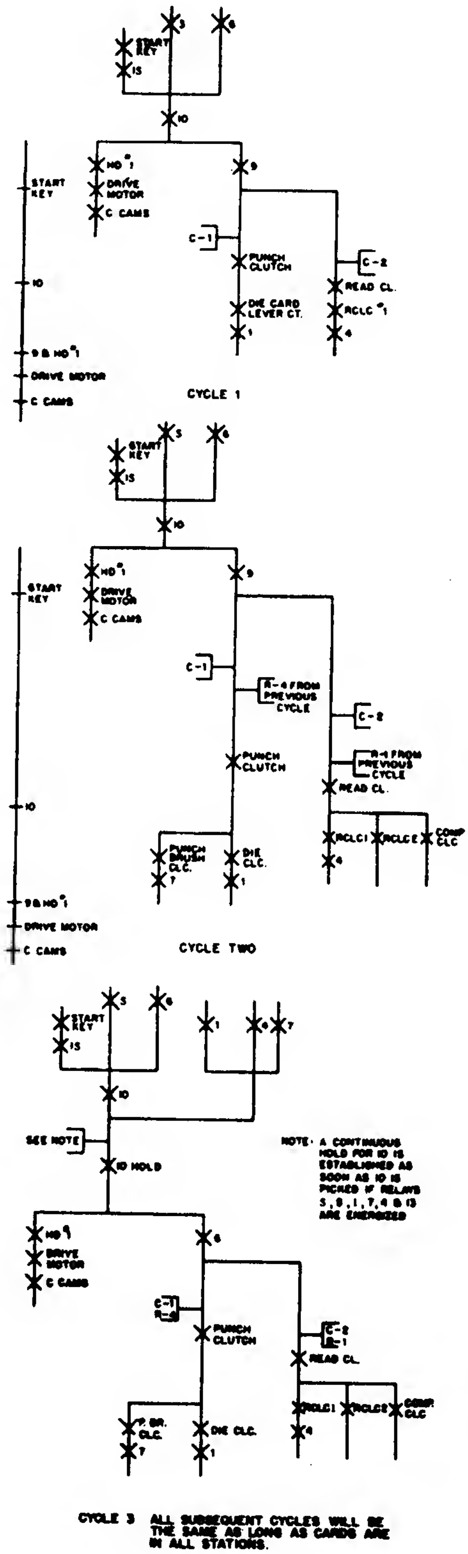


Figure 59. Function Chart — Reproducing Operation

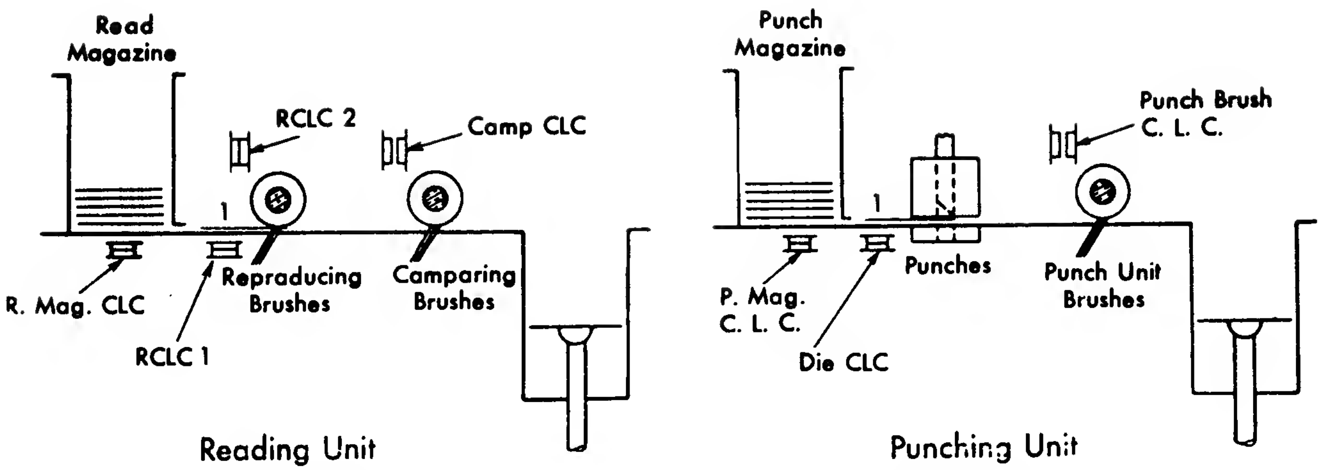


Figure 60. Condition of Card Levers at End of First Feed Cycle

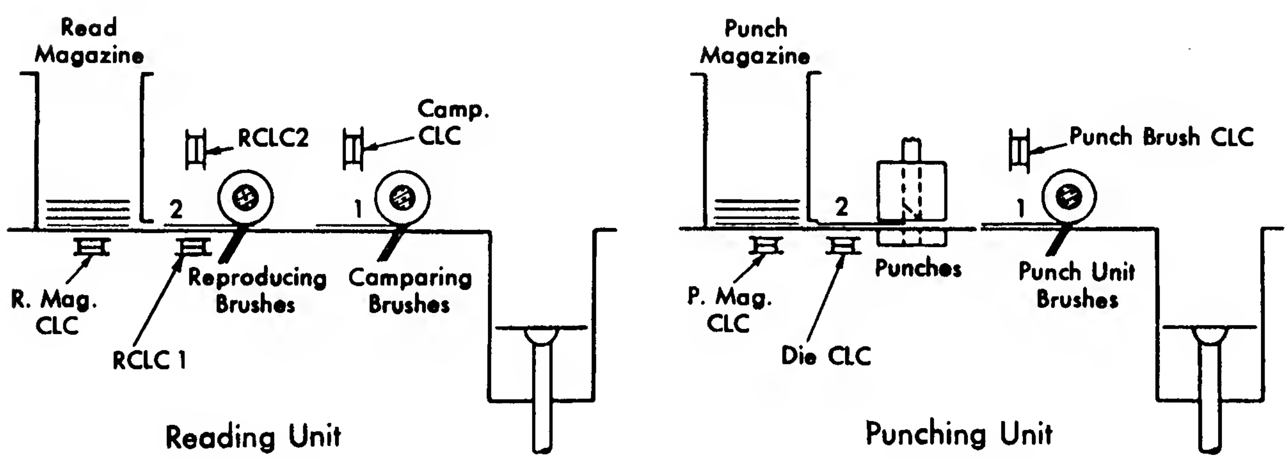


Figure 61. Condition of Card Levers at End of Second Feed Cycle

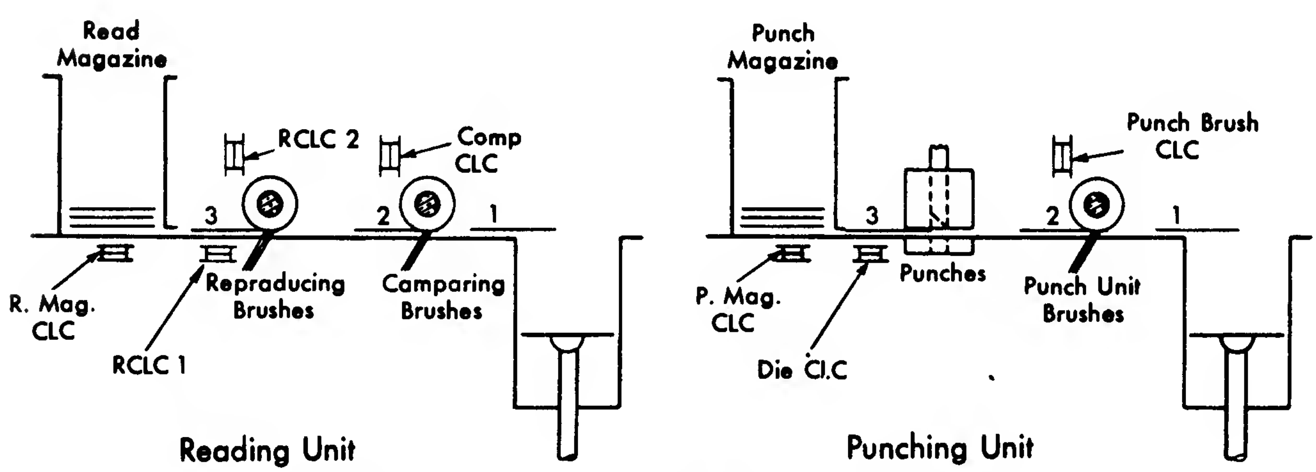


Figure 62. Condition of Card Levers at End of Third Feed Cycle

Read and Punch Circuits

OBJECTIVE: To show how the punch magnets are energized from the reproducing brushes when a hole is read.

1. Read CLC2 is closed during the second feed cycle and all subsequent cycles. 7B
2. Punch magnet relays R47 through 53 are energized on each punch feed cycle by P1. 7B
3. Punch magnets are energized by P1, C11, 12, 13, 14, and R1 through Read CLC2, hole in card, punch magnet relay points. 7A, 7B

Interlock Circuits

When reproducing from one file of cards to another, it is necessary that the two feed units remain in step with each other. For each card fed from the read magazine, there must be a card fed from the punch magazine, and vice versa. Interlocking circuits have been incorporated to insure this type of operation.

A. Feed Magazine Interlocks

OBJECTIVE: To prevent the machine from operating unless both magazines are the same; i. e., both have cards in them or are both empty.

1. R13 and R10 will not be energized by the start key if either 6-2 or 3-2 are transferred without the other. 4B

B. Feed Clutch Interlocks

OBJECTIVE: To provide the proper feed to keep the cards in step even though one should fail to feed.

1. The punch clutch is energized by C1 through the 4-1 N/O point and the read clutch through C2 and 1-1 N/O during normal operation.
2. If a card should fail to feed in the read unit, the 4-1 point would return to normal insuring a circuit to the read clutch only.
3. If a card failed to feed in the punch unit, the 1-1 point would return to normal insuring a punch feed only on the next cycle.

Verifying Reproduced Information

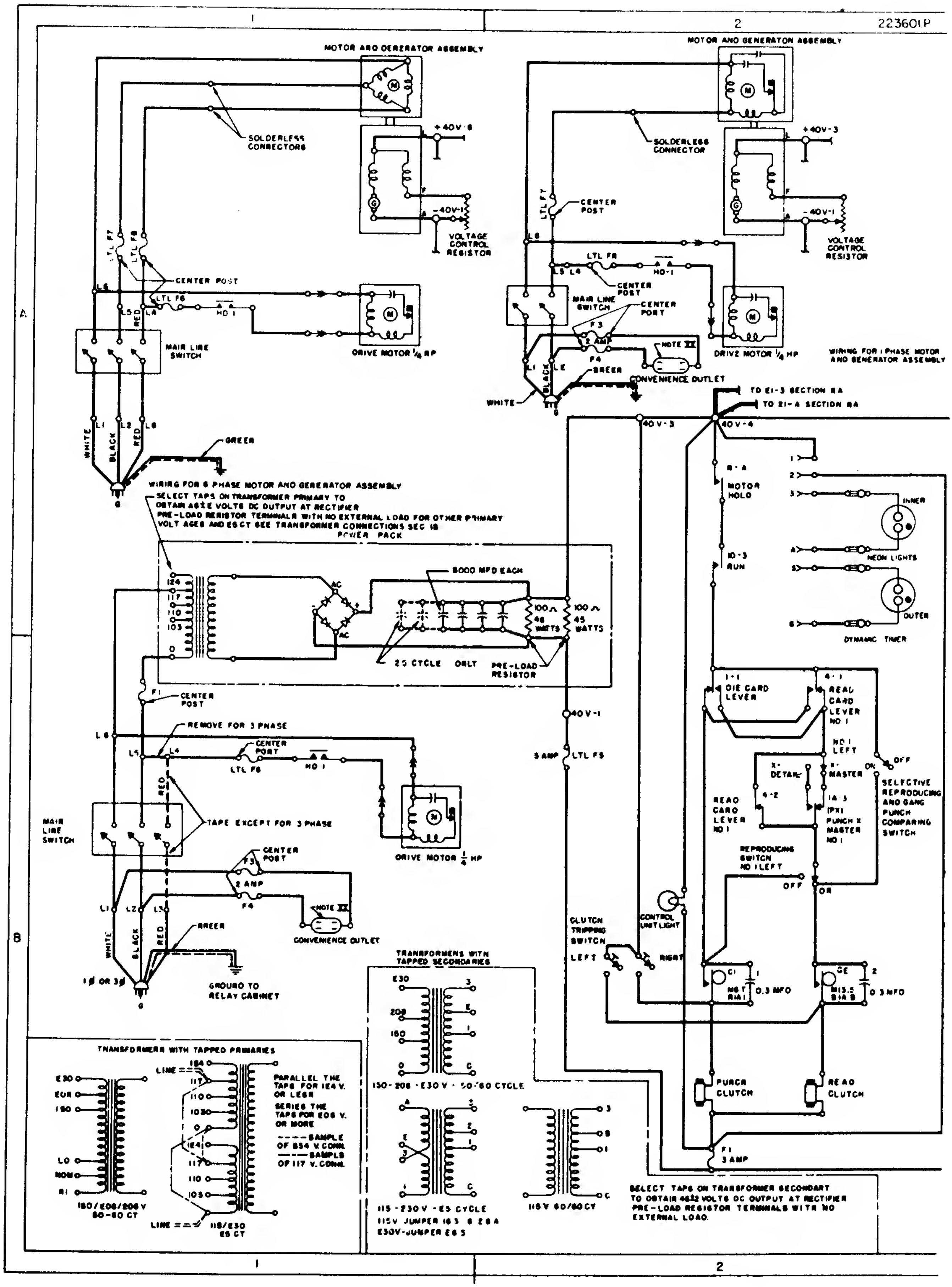
The accuracy of the punching may be verified in the comparing unit simultaneously with the reproducing operation. The punch brushes read the newly punched card one station after the punch station. The punches in the two cards are compared. If they are alike, the machine will continue in operation; but if they are not alike, the machine will stop and the error light will signal the discrepancy.

The comparing magnets are wound with two coils so connected that if a circuit is completed to either magnet coil, a magnetic field will be formed that will attract the armature. If circuits are completed to both coils, the magnetic effects of the coils will be such that they will neutralize each other and the armature will not be attracted.

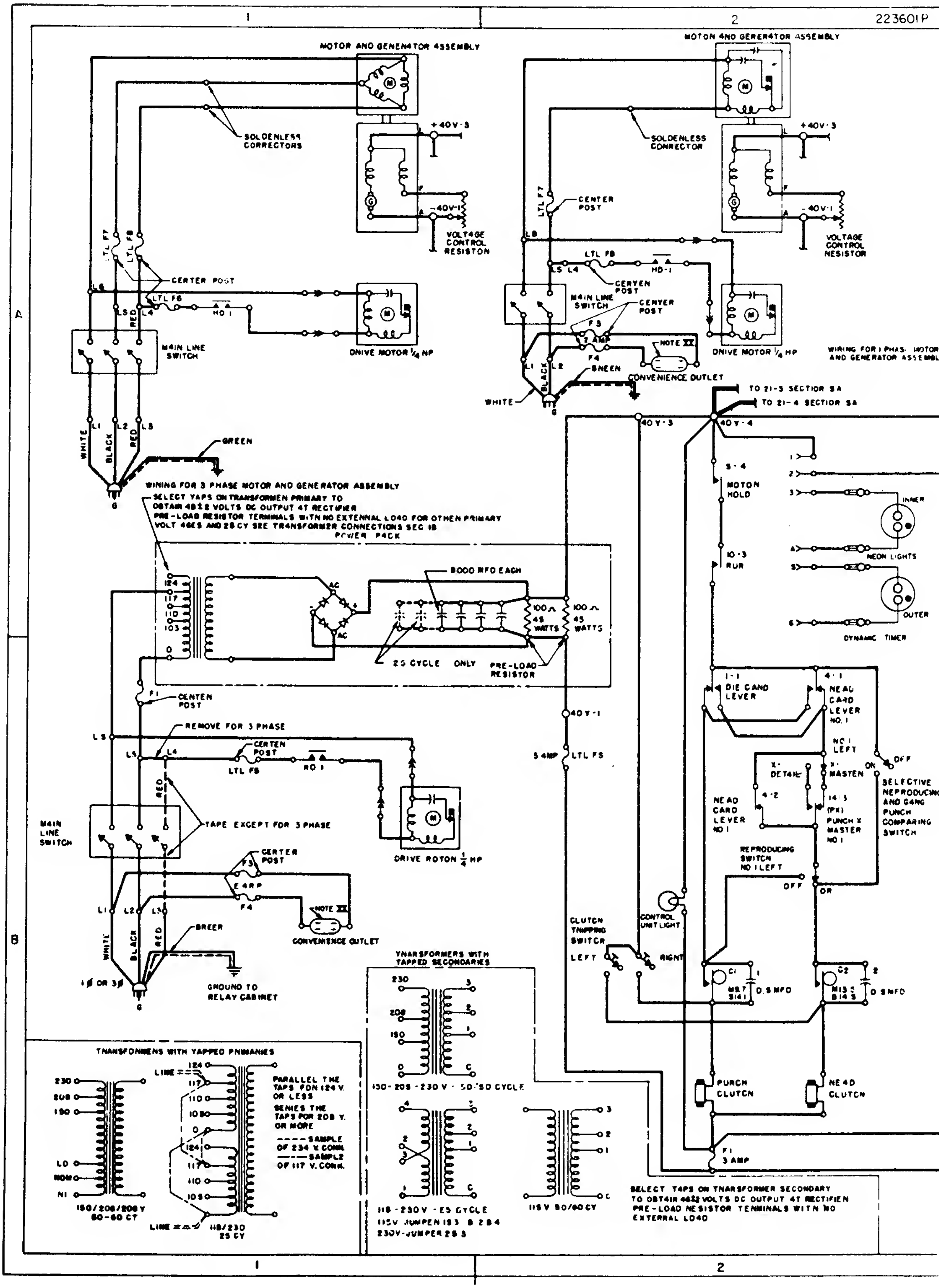
When any one of the comparing magnet armatures is attracted, a pawl is released to indicate the position in error, and the check bail is transferred to its operating position to transfer the check bail (comparing) contacts.

OBJECTIVE: To permit the machine to operate normally if no error occurs, but to stop the machine and turn on the error light if an error does occur.

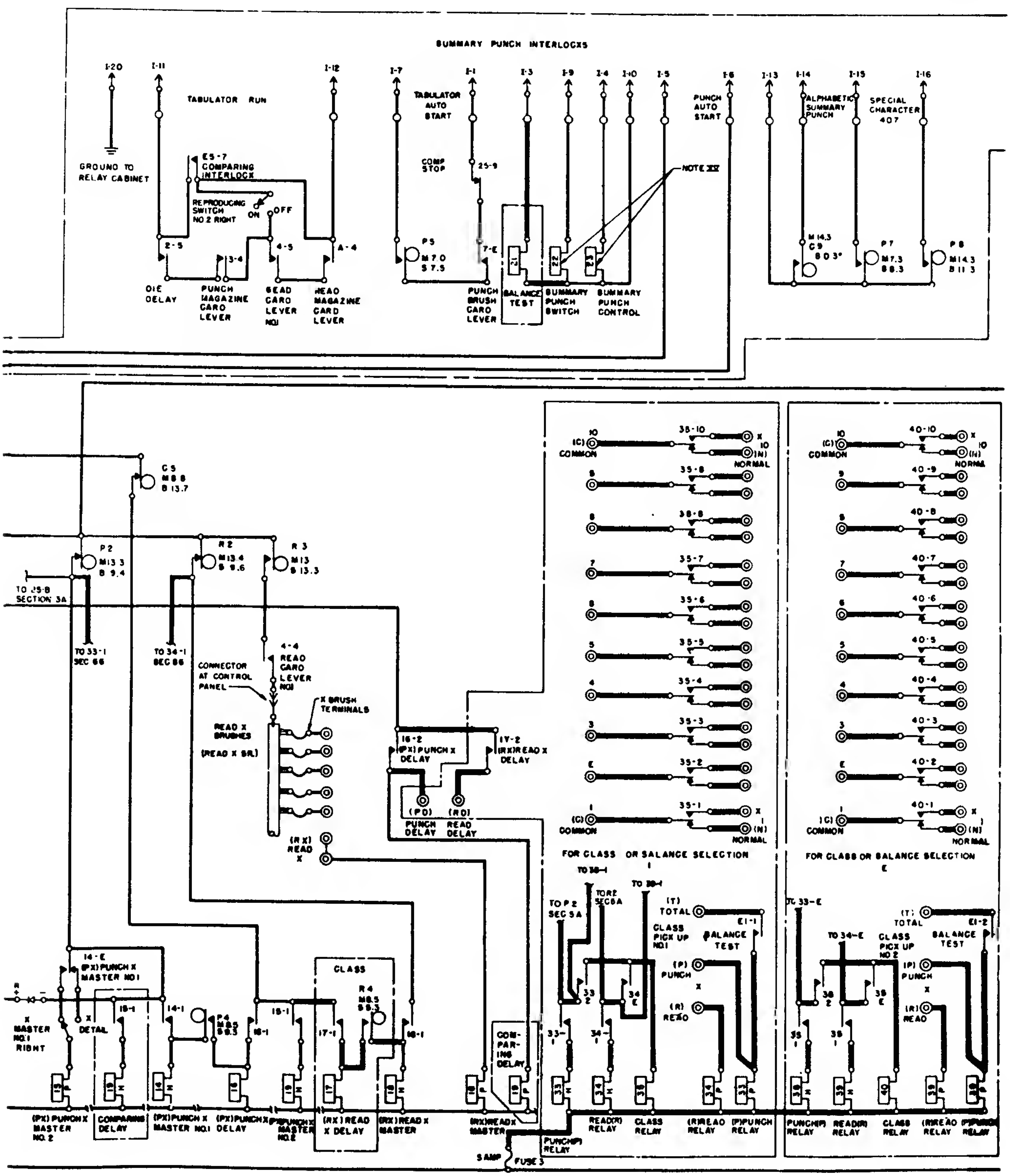
1. The two comparing magnets for a single position are impulsed simultaneously from the comparing and punch brushes with a no-error condition. 8B
2. If a circuit is completed to either of the two comparing magnets alone, the comparing contact left is transferred. 4A
3. The R13 hold circuit is opened and a circuit to the comparing signal light is completed by the transfer of the comparing contact left. 4A
4. 13-2 N/O interrupts the R10 hold circuit, and the machine stops. 4B
5. R25 is energized through the comparing contact left as soon as R10 is de-energized. 4B

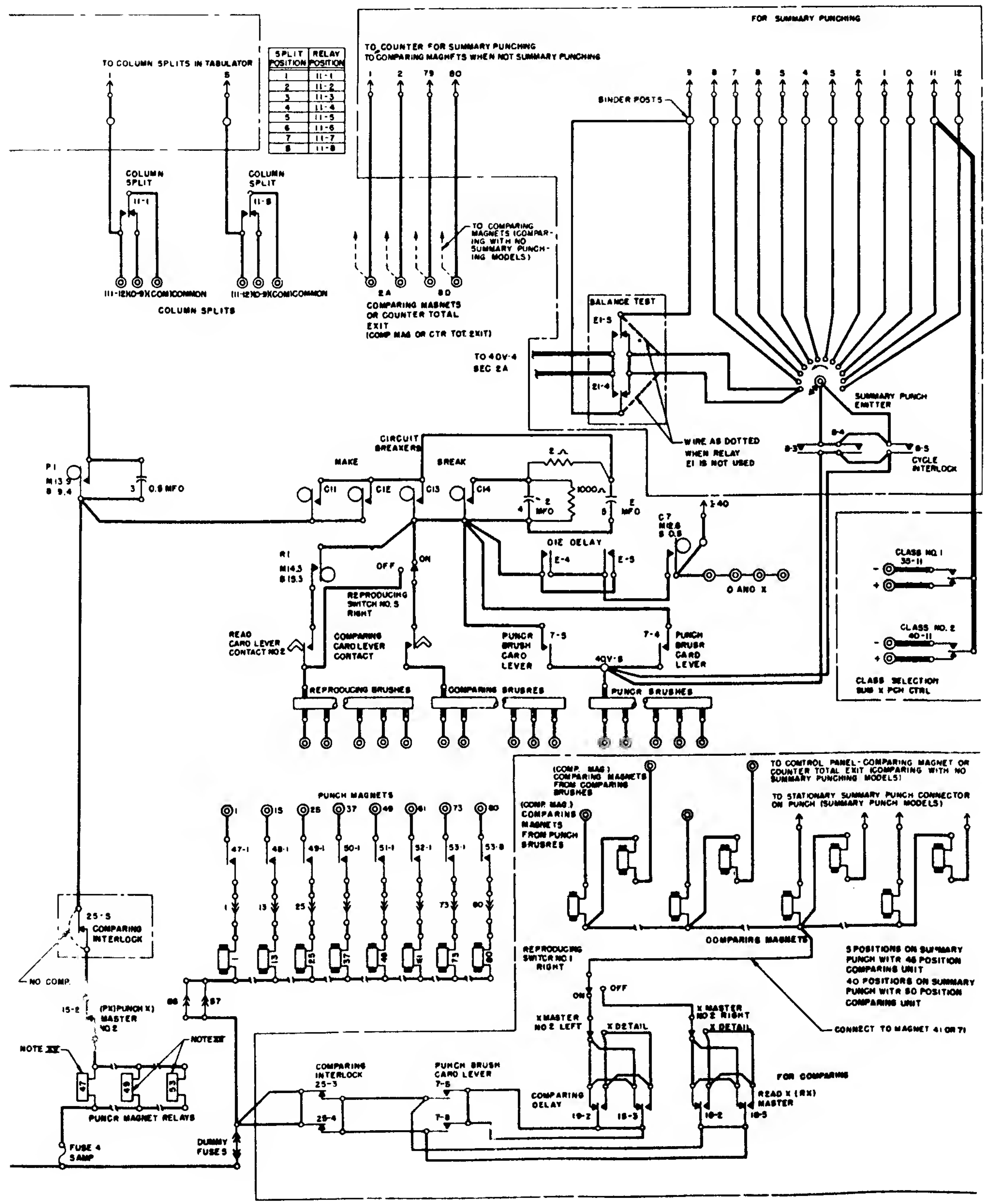


223601P
1
2
MOTOR AND GENERATOR ASSEMBLY
SOLDERLESS CONNECTORS
SOLDERLESS CONNECTOR
+40V-6
+40V-3
-40V-1
VOLTAGE CONTROL RESISTOR
CENTER POST
MAIN LINE SWITCH
DRIVE MOTOR 1/4 HP
WIRING FOR 1 PHASE MOTOR AND GENERATOR ASSEMBLY
CONVENIENCE OUTLET
NOTE XX
GREEN
WHITE
BLACK
RED
TO EI-3 SECTION RA
TO 21-A SECTION RA
WIRING FOR 3 PHASE MOTOR AND GENERATOR ASSEMBLY
SELECT TAPS ON TRANSFORMER PRIMARY TO OBTAIN 46±2 VOLTS DC OUTPUT AT RECTIFIER PRE-LOAD RESISTOR TERMINALS WITH NO EXTERNAL LOAD FOR OTHER PRIMARY VOLTAGES AND 25 CY SEE TRANSFORMER CONNECTIONS SEC 18
POWER PACK
5000 MFD EACH
100 Ω 45 WATTS
25 CYCLE ONLY
PRE-LOAD RESISTOR
REMOVE FOR 3 PHASE
TAPE EXCEPT FOR 3 PHASE
5 AMP LTL F5
2 AMP
GROUND TO RELAY CABINET
1Ø OR 3Ø
MOTOR HOLD
RUN
INNER
NEON LIGHTS
OUTER
DYNAMIC TIMER
DIE CARD LEVER
READ CARD LEVER NO 1
SELECTIVE REPRODUCING AND GANG PUNCH COMPARING SWITCH
REPRODUCING SWITCH NO 1 LEFT
CLUTCH TRIPPING SWITCH
CONTROL UNIT LIGHT
PUNCH CLUTCH
READ CLUTCH
F1 3 AMP
0.3 MFD
TRANSFORMERS WITH TAPPED SECONDARIES
130-208-230 V - 50/60 CYCLE
115-230 V - 25 CYCLE
115V JUMPER 1&3 & 2&4
230V-JUMPER 2&3
115 V 50/60 CY
TRANSFORMERS WITH TAPPED PRIMARIES
PARALLEL THE TAPS FOR 124 V. OR LESS
SERIES THE TAPS FOR 208 V. OR MORE
SAMPLE OF 234 V. CONN.
SAMPLE OF 117 V. CONN.
180/208/230 V 50-60 CY
115/230 25 CY
SELECT TAPS ON TRANSFORMER SECONDARY TO OBTAIN 46±2 VOLTS DC OUTPUT AT RECTIFIER PRE-LOAD RESISTOR TERMINALS WITH NO EXTERNAL LOAD.



223601P
MOTOR AND GENERATOR ASSEMBLY
SOLDERLESS CONNECTORS
+40V-3
-40V-1
VOLTAGE CONTROL RESISTOR
CENTER POST
MAIN LINE SWITCH
DRIVE MOTOR 1/4 HP
WHITE
BLACK
RED
GREEN
WIRING FOR 3 PHASE MOTOR AND GENERATOR ASSEMBLY
SELECT TAPS ON TRANSFORMER PRIMARY TO OBTAIN 48±2 VOLTS DC OUTPUT AT RECTIFIER PRE-LOAD RESISTOR TERMINALS WITH NO EXTERNAL LOAD FOR OTHER PRIMARY VOLTAGES AND 25 CY SEE TRANSFORMER CONNECTIONS SEC 18
POWER PACK
8000 MFD EACH
100 Ω 45 WATTS
25 CYCLE ONLY
PRE-LOAD RESISTOR
REMOVE FOR 3 PHASE
TAPE EXCEPT FOR 3 PHASE
DRIVE MOTOR 1/4 HP
CONVENIENCE OUTLET
1Ø OR 3Ø
GROUND TO RELAY CABINET
TRANSFORMERS WITH TAPPED PRIMARIES
PARALLEL THE TAPS FOR 124 V. OR LESS
SERIES THE TAPS FOR 208 V. OR MORE
SAMPLE OF 234 V. CONN.
SAMPLE OF 117 V. CONN.
150/208/208 V 50-60 CY
118/230 25 CY
TRANSFORMERS WITH TAPPED SECONDARIES
150-208-230 V · 50/60 CYCLE
115-230 V · 25 CYCLE
115V JUMPER 1&3 & 2&4
230V-JUMPER 2&3
115 V 50/60 CY
MOTOR AND GENERATOR ASSEMBLY
SOLDERLESS CONNECTOR
DRIVE MOTOR 1/4 HP
WIRING FOR 1 PHAS. MOTOR AND GENERATOR ASSEMBLY
CONVENIENCE OUTLET
TO 21-3 SECTION 5A
TO 21-4 SECTION 5A
40V-3
40V-4
40V-1
MOTOR HOLD
RUN
NEON LIGHTS
INNER
OUTER
DYNAMIC TIMER
DIE CARD LEVER
READ CARD LEVER NO. 1
SELECTIVE REPRODUCING AND GANG PUNCH COMPARING SWITCH
REPRODUCING SWITCH NO 1 LEFT
CONTROL UNIT LIGHT
CLUTCH TRIPPING SWITCH
LEFT
RIGHT
0.5 MFD
PUNCH CLUTCH
READ CLUTCH
F1 3 AMP
SELECT TAPS ON TRANSFORMER SECONDARY TO OBTAIN 48±2 VOLTS DC OUTPUT AT RECTIFIER PRE-LOAD RESISTOR TERMINALS WITH NO EXTERNAL LOAD


SUMMARY PUNCH INTERLOCKS
TABULATOR RUN
GROUND TO RELAY CABINET
COMPARING INTERLOCK
REPRODUCING SWITCH NO 2 RIGHT
ON
OFF
DIE DELAY
PUNCH MAGAZINE CARD LEVER
READ CARD LEVER NO1
READ MAGAZINE CARD LEVER
TABULATOR AUTO START
COMP STOP
PUNCH BRUSH CARD LEVER
BALANCE TEST
SUMMARY PUNCH SWITCH
SUMMARY PUNCH CONTROL
NOTE XX
PUNCH AUTO START
ALPHABETIC SUMMARY PUNCH
SPECIAL CHARACTER 407
TO 25-8 SECTION 3A
TO 33-1 SEC 6B
TO 34-1 SEC 6B
CONNECTOR AT CONTROL PANEL
X BRUSH TERMINALS
READ X BRUSHES
(READ X BR.)
(RX) READ X
(PX) PUNCH X DELAY
(RX) READ X DELAY
(PD) PUNCH DELAY
(RD) READ DELAY
COMMON
NORMAL
FOR CLASS OR BALANCE SELECTION
(T) TOTAL
CLASS PICK UP NO1
CLASS PICK UP NO 2
BALANCE TEST
(P) PUNCH
(R) READ
CLASS
(PX) PUNCH X MASTER NO 1
X MASTER NO1 RIGHT
X DETAIL
COMPARING DELAY
(PX) PUNCH X MASTER NO 2
(PX) PUNCH X MASTER NO1
(PX) PUNCH X DELAY
(RX) READ X DELAY
(RX) READ X MASTER
COMPARING DELAY
PUNCH(P) RELAY
READ(R) RELAY
CLASS RELAY
(R) READ RELAY
(P) PUNCH RELAY
5 AMP
FUSE 3



SPLIT POSITION	RELAY POSITION
1	11-1
2	11-2
3	11-3
4	11-4
5	11-5
6	11-6
7	11-7
8	11-8

WIRE CONTACT RELAY CHART

	RELAY NO	COILS P	COILS H	CONTACT POINTS 1	2	3	4	5	6	7	8	9	10	11	12	PART NUMBER
*	1	38		28	48	48	38									104783
	2	48	48	48	48	8A	8A	5A								188188
*	3	38		48	48	58	8A	48								188187
	4	**	38	58	28	48	58	8A								188188
	5															
	6	**	38	48	58	48	8A									188188
	7	**	38	48	5A	88	88	78	78	48						888738
	8	38		38	48	8X	8X	8X								188198
*	9	48		48	38	48	8A									104783
	10	48	48	48	48	5A	48	38	38	38						888738
	11	48		7A	7A	7X	7A	7A	7A	7A	7A	38	48			188198
	12															
	13	48	48	48	48	48										186808
	14	48	58	88	58	58										188208
	15	88	58	58	78											188807
	16	58		58	58											188E08
	17	88		58	58											198208
	18	88	88	58	68	88										198207
	19	88	58	58	88	88										198208
	20															
	E1	6X		88	88	8A	8A									198188
*	22	6A		4A	4A	48	48									104788
*	23	6A		48	38											104788
	25	48	38	38	58	78	78	78	48	8A	38	8X				288738
	26															
	27															
	28															
	29															
	30															
	31															
	32															
	33	66	68	88	R8											188807
	34	68	68	68	88											186207
	35	88		88	88	68	88	66	6A	6A	6X	8A	8A	8A		188188
	36															
	37															
	38	66	R8	68	66											196207
	3R	66	88	88	56											196207
	40	88		68	88	88	88	88	8A	8A	8A	8A	6A	6X		196188
	41															
	42															
* *	47 TRROUGH 53	SEC 7 8 (SEE PUNCR MAGNET RELAY CRART FOR POSITIONS)														198187

* SEE NOTE XX

** PICK COIL NOT USED ON TRESE RELATS

CAM NO	CAM LOC	MAKE TIME	TOL	BREAK TIME	TOL	DUR-ATION	CAM NAME	PART NUMBER
C1	88	8.7	±1/2	14.1	±1/2	38°	PUNCH CLUTCR	118108
C2	28	13.8	±1/2	14.8	±1/8	38°	READ CLUTCR	118108
C3	58	8	±1/2	[illegible]	±1/2	348°	MOTOR STOP CORTROL	181737
C4	4A	8.8	±1/2	11.8	±1/2	100°	COLUMR SPLIT CONTROL	184378
C5	8A	8.8	±1/2	13.7	±1/2	50°	DELAY HOLD	118107
C8								
C7	8A	18.8	±1/2	0.8	±1/8	80°	ZERO AND X	118107
C8								
C9	8X	14.3	±1/2	0.3	±1/2	78°	SUMMARY PUNCH ALPRABET	123881
C10								
C11	7A	MAKE	±1/4				CIRCUIT BREAKER	184332
C12	7A	MAKE	±1/4				CIRCUIT BREAKER	184331
C13	7A			BREAK	±1/4		CIRCUIT BREAKER	124331
C14	7X			BREAK	±1/4		CIRCUIT BREAKER	18433
P1	7A	13.8	±1/2	2.4	±1/2	3/88	CIRCUIT BREAKER CORTROL	10840
P2	8A	13.3	±1/2	8.4	±1/2	13/14	PURCR X HOLD	10842
P3	8A	13	+0-1/2	13.8	±1/2	1/28	PURCR X IMPULSE	10R40
P4	88	8.8	±1/2	8.3	±1/2	1/88	DELAY RELAY PICKUP	10940
P5	8A	7.0	±1/2	7.8	±1/2	1/28	TABULATOR AUTO START	10R40
P6	4A	8.7	±1/8	8.2	±1/8	1/88	START ROLD	10240
P7	8A	7.3	±1/8	8.3	±1/2	1/14	SPECIAL CHARACTER 407	10R401
P8	8A	14.3	±1/2	11.3	±1/2	2/14	SPECIAL CHARACTER 407	109404
R1	7A	14.3	±1/2	13.3	±1/2	13/14	BREAKER CONTROL	10242
R2	8A	13.4	±1/2	8.8	+1/2-0	13/14	X ROLD	10948
R3	8A	13	+0-1/2	13.8	±1/2	1/28	X IMPULSE	JOR40
R4	88	8.8	±1/2	8.3	±1/2	1/88	DELAY RELAY	10240
R5	48	2.7	±1/2	2.E	±1/2	1/28	START HOLD	10240

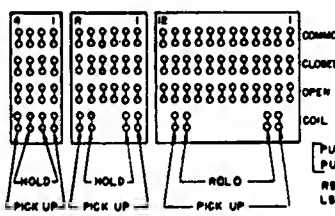
SUMMARY PUNCH EMITTER

PURCH BRUSHES

REPRODUCING AND COMPARING BRUSHES

PURCR X BRUSHES

READ X BRUSHES



RELAY MOULDINGS (CABLE SIDE VIEW)

REPRO I AND DIE CARD LEVER CONTACT (FIRST CARD)

REPRO I AND DIE CARD LEVER CONTACT (LAST CARD)

REPRO 2 CARD LEVER CONTACT (FIRST CARD)

REPRO 2 CARD LEVER CONTACT (LAST CARD)

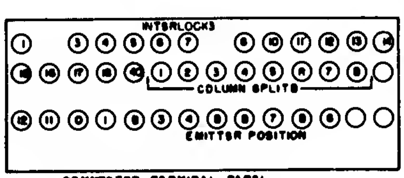
PUNCR & COMPARING CARD LEVER CONTACT (FIRST CARD)

PURCR & COMPARING CARD LEVER CONTACT (LAST CARD)

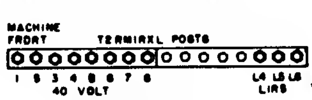
READ & PUNCH MAGAZINE CARD LEVER CONTACT (LAST CARD)

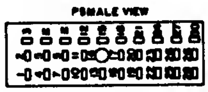
PUNCH MAGNET RELAY CHART

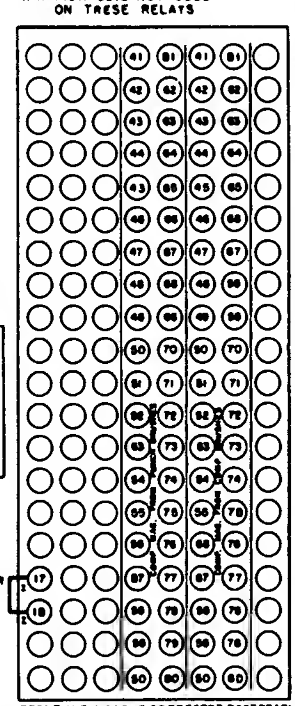
MAG NO	REL POS	MAG NO	REL POS	MAG NO	REL POS	MAG NO	REL POS	MAG NO	REL POS	MAG NO	REL POS
1	47-1	15	48-3	28	49-5	43	50-7	57	51-8	71	52-11
2	47-2	16	48-4	30	49-6	44	50-8	58	51-10	72	52-12
3	47-3	17	48-5	31	49-7	45	50-9	59	51-11	73	53-1
4	47-4	18	48-6	32	49-8	46	50-10	60	51-12	74	53-2
5	47-5	19	48-7	33	49-9	47	50-11	61	52-1	75	53-3
6	47-6	20	48-8	34	49-10	48	50-12	62	52-2	76	53-4
7	47-7	21	48-9	35	49-11	49	51-1	63	52-3	77	53-5
8	47-8	22	48-10	36	49-12	50	51-2	64	52-4	78	53-6
9	47-9	23	48-11	37	50-1	51	51-3	65	52-5	79	53-7
10	47-10	24	48-12	38	50-2	52	51-4	66	52-6	80	53-8
11	47-11	25	49-1	39	50-3	53	51-5	67	52-7		
12	47-12	26	49-2	40	50-4	54	51-6	68	52-8		
13	48-1	27	49-3	41	50-5	55	51-7	69	52-9		
14	48-2	28	49-4	42	50-6	56	51-8	70	52-10		



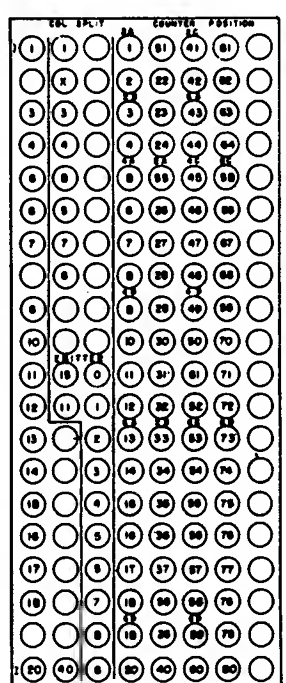
CONNECTOR TERMINAL PANEL




JONES PLUG SOCKET FEMALE VIEW



FRONT VIEW-CABLE CONNECTOR RECEPTACLE ON SUMMARY PUNCH



FRONT VIEW-TABULATOR CABLE RECEPTACLE REAR VIEW - SUMMARY PUNCH CONNECTOR

PUNCH CARD PICKER

READ CARD PICKER

PUNCH STROKE — TOP / BOTTOM

INTERMITTENT MOVEMENT

PUNCH CARD FEED CLUTCH ENGAGES AND DISENGAGES HERE

READING CLUTCH ENGAGES AND DISENGAGES HERE

PUNCH FEED ROLL CLUTCH ENGAGES AND DISENGAGES HERE

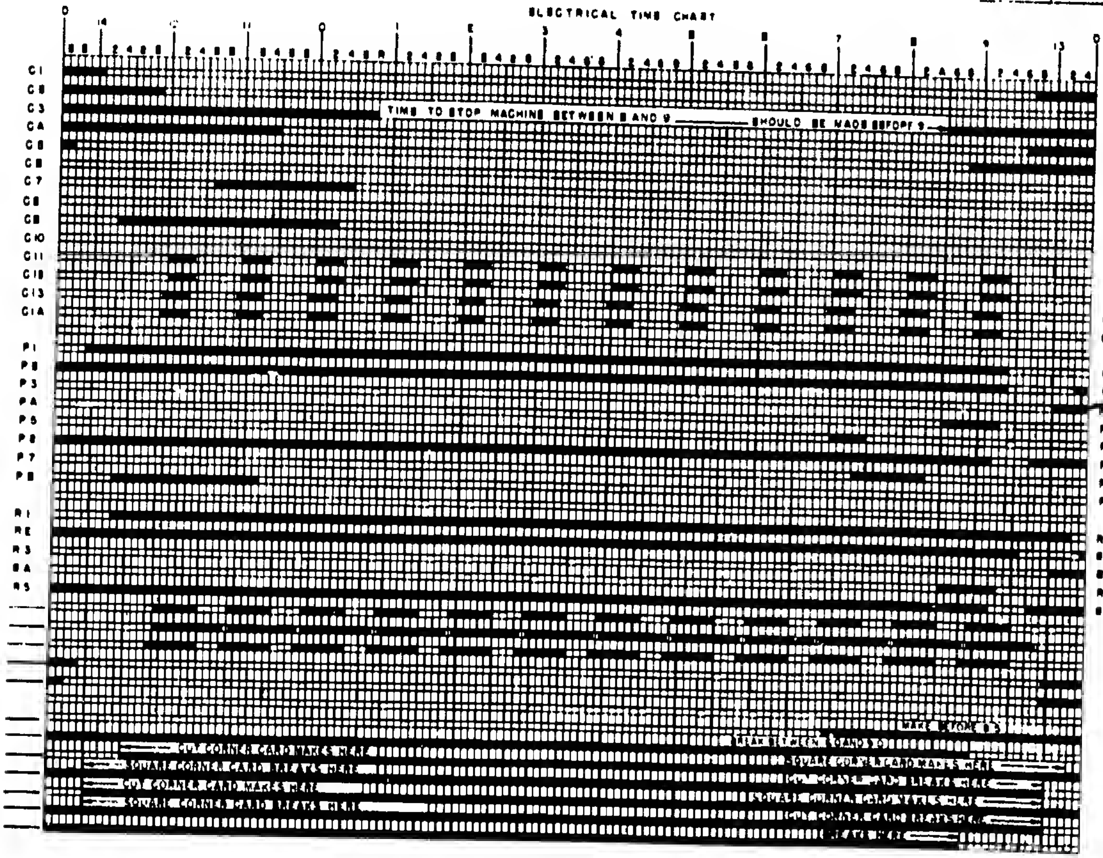

DYNAMIC TIMER SOCKET FEMALE VIEW

SWITCH	LOC
MAIN LINE	1,2,3
START	48
STOP	48
REPRO NO1- LEFT	28
REPRO NO1- RIGHT	68
REPRO NO2-LEFT	48
REPRO NO2-RIGHT	5A
REPRO NO 3-LEFT	4X
REPRO NO 3-RIGHT	7A
SEL REPRO AND DP COMP	58
R MASTER NO1- LEFT	28
X MASTER NO1- RIGHT	58
X MASTER NO2-RIGHT	58
CLUTCH TRIPPING R AND L	28
X MASTER NO 2 LEFT	68

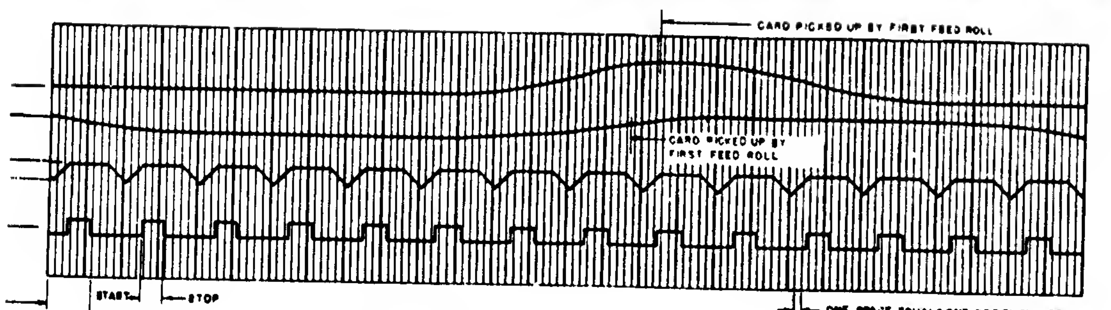
12 | NONE | 223601 P

DATE	CHANGE NO
1-18-49	12 AOBL
3-30-49	15807
8-16-49	15560
5-24-49	159601
9-14-49	[illegible]
11-31-49	18595
12-18-49	18819
12-19-50	16925 A
3-29-50	18938
10-28-50	17234
1-24-51	17490
1-29-51	18172
4-9-51	18172 A
4-25-51	17699C
7-18-51	18349
2-28-52	18801 A
2-2-53	83
8-18-53	438
11-17-53	324 A
5-27-54	[illegible]
11-10-54	20[illegible]5F
[illegible]-28-55	22788
[illegible]-4-55	[illegible]
9-13-55	[illegible]

ELECTRICAL TIME CHART

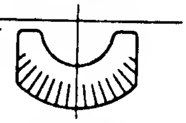


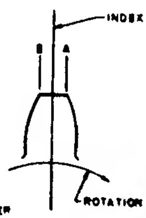
MECHANICAL TIME CHART

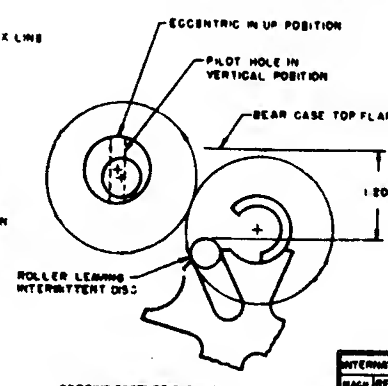


SETTING OF STACKER FEED ROLL SHAFT

WITH MACHINE INDEX SET AT A — THESE SURFACES TO BE HORIZONTAL







SETTING ECCENTRIC SHAFT TO INTERMITTENT DISC

NOTES

X - MACHINE OVERTHROW WILL VARY WITH OIL VISCOSITY AND MECHANICAL FRICTION. CAM SHOULD BE TIMED AFTER MACHINE LOSES STIFFNESS AND WHEN OIL IS WARM

XI - NAMES SHOWN BY ABBREVIATIONS IN PARENTHESIS ARE AS SHOWN ON CONTROL PANEL

XII - TIME MAKE CAMS C11 AND C12 TO MAKE ON INDEX LINE. TIME C13 TO BREAK AT "A" 3 TEETH AFTER LINE. TIME C14 TO BREAK AT "B" 3 TEETH AFTER LINE. DIFFERENCE IN BREAK TIME BETWEEN C13 AND C14 IS DISTANCE BETWEEN "A" AND "B"

XIII - ADJUST FEED KNIVES TO TRAVEL .015 PAST POINT WHERE FRONT EDGE OF CARD IS STOPPED BY FIRST FEED ROLL

XIV - WIRE COLOR CODE ON RELAY GATE ONLY
POINTS 1, 5, & 9 - BLACK WIRES
POINTS 2, 6, & 10 - GREEN WIRES
POINTS 3, 7, & 11 - BLACK-RED WIRES
POINTS 4, 8, & 12 - BLACK-GREEN WIRES

XV THE COILS OF RELAYS 1, 3, 9, 22, 28, AND (47 THRU 55 INCLUSIVE) ARE CONNECTED AS SHOWN BELOW

11 | 12

INTERNATIONAL BUSINESS MACHINES CORP					
MACH	REPRODUCER SUMMARY PUNCH				
		MODEL	514		
NAME	WIRING DIAGRAM				
DRAWN	EWC	12-8-48	SCALE	NONE	
CHECK	JDD	12-13-48	TRAC	JNA	[illegible]
APPROVED	GFD	12-13-48	[illegible]	EJM	[illegible]

APPENDIX III

Excerpts from the Customer Engineering Reference Manual of the IBM 514 Punch Reprinted Courtesy of IBM

Feed Roll Opening Device (Figure 31)

1. Adjust eccentric studs to provide for feed rolls opening .020" at both ends, and a minimum of .015" clearance at the center of the rolls when on high dwell of opening cams at 1 tooth past 4.

2. To time the roll opening cams, loosen cams on the shaft and turn the machine to 4 teeth past 5. Turn roll opening cams back clockwise against cam follower rollers and tighten cam set screws.

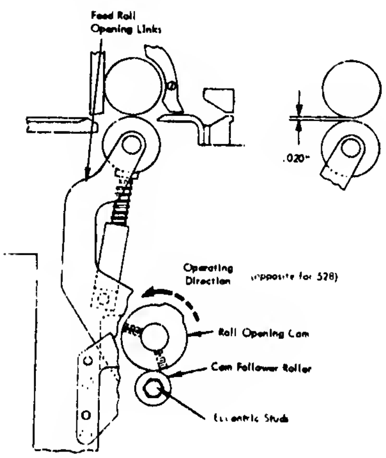


Figure 31. Feed Roll Opening Device

Card Friction Springs (Figure 32)

These springs are of prime importance and are a factor in maintaining accurate punching registration, because they must hold the card accurately in position until the first feed rolls close to carry it to the punch station.

1. Turn the machine until the feed roll opening device fully opens the first feed rolls.

2. Insert an IBM card between the card friction springs and the card guide, position the card friction springs vertically in their elongated holes to adjust for a moderate drag on the card. Tension is to be even on both springs.

Feed Roll Tension

Feed roll tension is fixed (not adjustable) and is determined by the compression springs in the feed roll pressure brackets.

It is important that feed roll pressures be checked for evenness of tension over the entire roll; this should be done periodically to insure accurate card feeding.

In case weak or broken springs are found, it is recommended that all the springs in that bracket be replaced. When replacements are made, be sure to use the correct spring.

To aid in removal and re-assembly, use 5-40 screws in the lower feed roll pressure bracket spring wells to hold the pressure shoes in place.

Compression spring action on the bottom of the pressure shoes often causes burrs which result in binding pressure shoes, thus, affecting feed roll tension. Check for this condition. Remove the burrs or replace the shoe.

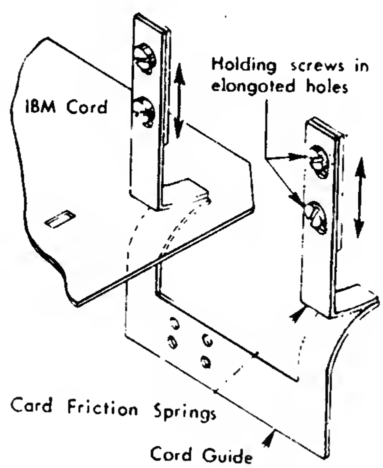


Figure 32. Card Friction Spring Adjustments

Drive Gear Housing—Checking

1. Pins in geneva gear assembly. A loose or partly sheared pin will often be indicated by variations in the vertical registration on a card. As an example, one and nine might be in registration vertically, and a five hole might be off. Air bubbles will often form in the oil film over a loose pin. If the pins holding the geneva dog one-tooth ratchet are bad, it is often possible to engage the dog and then, using a heavy screwdriver for leverage, rock the geneva gear back and forth without moving the shaft to which the one-tooth ratchet is pinned.

2. Oil pump for operation and oil level.

3. Oil seals for leakage. Oil leakage may be observed on the inside of the casting around the feed rolls. It is recommended that the oil cup cover on the drive housing be crimped to prevent it from properly seating on the oil cup. This will allow the passage of sufficient air to maintain normal pressure within the housing and will make the replacement of the oil seals unnecessary in many cases.

Lubrication

IBM 6

1. Roller throat wick.
2. Feed knife block-pivot stud.
3. Card lever pivot points.
4. Feed roll open device cam followers (followed by IBM 17).
5. Felt pad behind punches.
6. Interposers. Oil these very sparingly. Pull a card, soaked with IBM 6, between gummy or sticky interposers.
7. Punch magnet armature pivots.

IBM 9

1. Feed knife slide wicks.
2. The center bearing of first upper feed roll.
3. Oil cups in all lower feed roll pressure brackets.
4. Oil holes in lower feed roll end bearings.
5. Oil reservoirs in side frame castings. To lubricate, remove the felt and force oil down each oil tube until it flows from the lower end. Do not saturate the oil felts as this will cause a siphoning action, which causes the highest bearings to be deprived of oil. Replace the felt dry to act as a dust seal.
6. Contact roll spindle and key (followed by IBM 17).
7. Punch bail connecting pin oil cups.
8. Punch bail pivot shaft oil cups.
9. Punch stacker roll idler gear bearing.
10. Punch stacker felt washer.
11. Punch cam contact drive gear shaft bearings.
12. Driven pulley ratchet pawl pivots (if equipped).
13. Reverse friction lock pawl pivot (if equipped).
14. Index gear needle bearings.
15. Feed roll opening device cam follower roller.

IBM 12

1. Drive housing reservoir. IBM 15 is permissible if leakage occurs.

IBM 17

1. Feed roll drive gears—light film.
2. Magnet armatures—points where pull rods fasten.
3. Card levers—a light film between operating lever and pad on contact strap.
4. Feed knife slide rack and card picker shaft sector gear teeth; light film.
5. Stacker unit—7 gears—light film on teeth.

IBM 20

1. Eccentric shaft zerk fittings.

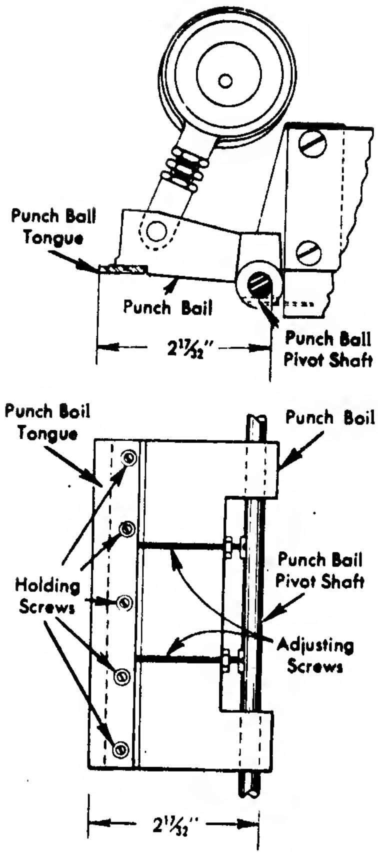


Figure 35. Punch Bail Tongue Adjustment

PUNCH BAIL TONGUE (Figure 35)

The punch bail tongue must be positioned on tha punch bail to provide for proper relationship (clearance and overlap) between tha bail tongue and the interposers, with interposers in either the normal or operated positions.

1. To adjust, loosen the five holding screws.

2. Position the punch bail tongue, relative to the punch bail by means of two adjusting screws, to obtain a uniform $2\frac{17}{32}$" from the left edge of the tongua to the right side of the punch bail pivot shaft.

3. To check this adjustment, operate the punch bail to a point where the punch bail tongue is just below the interposer engagement point (Figure 36). At this time, check for a .009" to .012" clearance between the punch bail tongue and the interposers.

If required, reposition the punch bail tongue to the bail (slightly alter the $2\frac{17}{32}$") to obtain the specified .009" to .012" clearance.

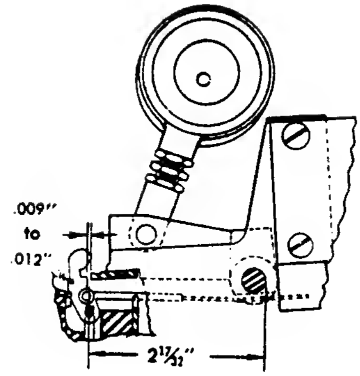


Figure 36. Punch Bail Tongue and Interposer Clearance

NOTE: When correctly positioned, further adjustment should not be necessary except when the punch bail or tongue is replaced.

PUNCH STOP BAR (Figure 37)

The punch stop bar should be positioned as near to the punches (over entire length) as possible without causing interference with the movement of punches.

Loosen the holding screws, move the bar in the elongated screw holes to position; tighten holding screws securely.

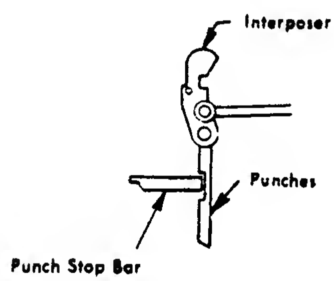


Figure 37. Punch Stop Bar

DIE ASSEMBLY (Figure 38)

To maintain the minimum clearance between the die and stripper assemblies the stop studs in the stripper must be held snugly against the die assembly. To adjust

1. Loosen the two left end and magnet unit mounting screws.

2. Adjust the vertical position of the magnet unit (left end) by means of the two adjusting screws. With the die latching bars resting on the side

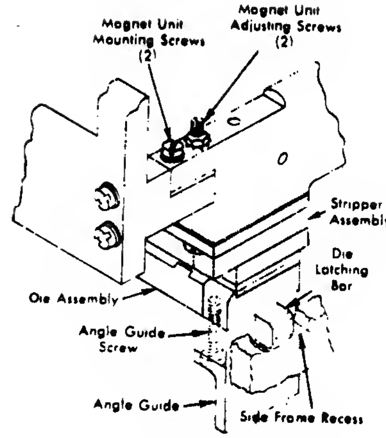


Figure 38. Die Assembly Adjustments

frame recesses, raise or lower the magnet unit to position the stripper stop studs snugly against the die assembly. Tighten the mounting screws.

3. Check the adjustment by removing and replacing the die several times; the die latching bars must have a slight drag as they enter and leave the casting recesses. Check both front and rear latching bars.

4. The die assembly angle guides facilitate insertion and removal of the die. To adjust, install the die assembly with the angle guide screws loose; press the guides outward and parallel to the side frames. Provide a maximum .005" clearance between the side frames and the guides. Tighten holding screws.

PUNCH BAIL CONNECTING LINKS (Figure 39)

The adjustabla connecting links provide the means of positioning the stroke of the punch bail tongue to the interposers. The stroke is adjusted to prevent the tongue from binding against the interposers at the upper limit of the stroke and for a minimum of punch travel into the die at the lower limit.

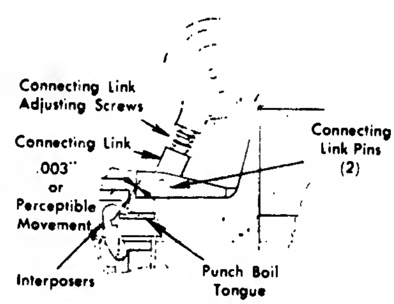


Figure 39. Punch Bail Connecting Link Adjustment

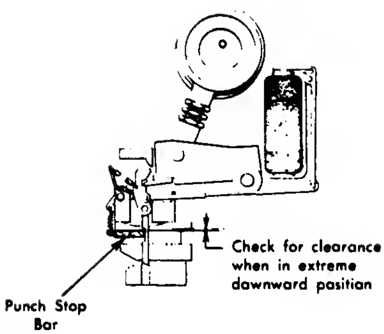


Figure 40. Connecting Link Adjustment Check

1. Remove the front connecting link pin.
2. Turn the machine to position the punch bail in its uppermost position at 1 tooth past any index line.
3. Loosen the locking nuts and adjust the rear connecting link adjusting screw to obtain a .003" clearance between the interposers and the punch bail tongue. Use either a .003" leaf gage or check for a perceptible movement of the interposers to the bail tongue, to determine this clearance.

In case the clearance varies from one end of the bail tongue to the other the .003" is to apply at the closest end.

4. Adjust the front connecting link adjusting screw so that the front punch bail connecting pin will slide freely into position in the punch bail and punch bail connecting links. This assures an even adjustment on both links and eliminates strain on the punch bail.

TO CHECK ADJUSTMENTS

CAUTION: *When turning by hand with the interposer knockoff bar removed, be sure all interposers are disengaged from the punch bail tongue before the top of the stroke.*

1. Engage an interposer at each end of the punch bail and turn the machine until the punch bail is at its lower limit of travel (Figure 40).
2. Press on the top of the engaged

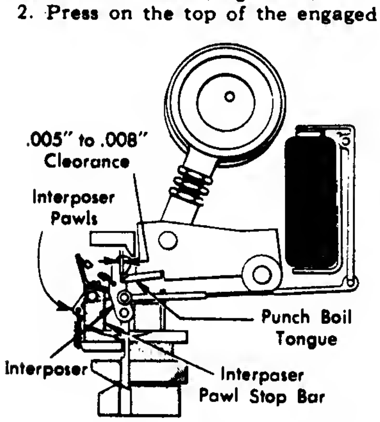


Figure 41. Interposer Pawl Stop Bar

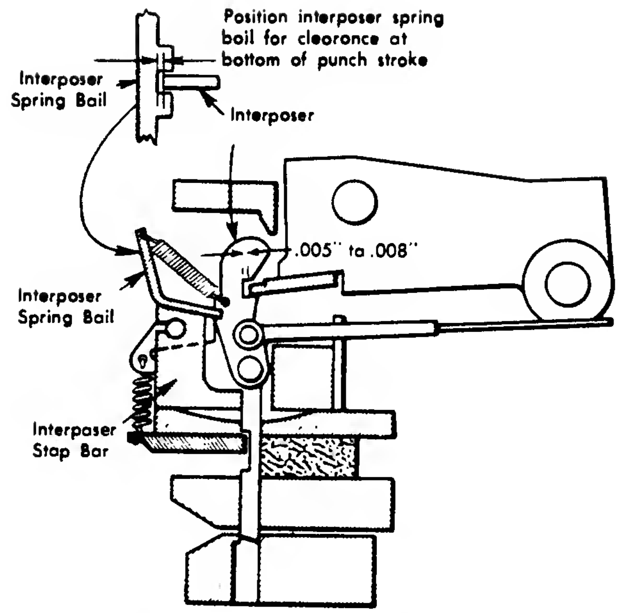


Figure 42. Interposer Spring Bail

interposers and carefully check for an additional downward movement of at least .005". This is to insure that the punches will not be driven against the punch stop bar.

3. Check this adjustment further, after other required adjustments have been made, by running approximately fifty cards through the machine, punching zeros in all 80 columns. The holes in all positions should be clearly punched; if not, it will be necessary to increase the punch travel slightly in order to successfully perform this test.

Punch travel into the die should always be held to a minimum, consistent with proper punching results; this will insure a longer die life and minimize pulling of card chips.

INTERPOSER PAWL STOP BAR (Figure 41)

The interposer stop pawl bar is positioned and pinned at the factory. The fixed horizontal position of this stop bar relative to a correctly positioned punch bail tongue ($2\frac{11}{32}$ adjustment) should provide a clearance of .005" to .008" between the interposers and the bail tongue.

Check for this .005" to .008" clearance when the interposers are engaged with the punch bail tongue and are driven to their extreme downward position by the punch bail.

In case the specified clearance is not present, it may be obtained by re-adjusting the position of the punch bail tongue on the punch bail (Figure 35).

INTERPOSER SPRING BAIL (Figure 42)

The interposer spring bail should be positioned horizontally on the interposer stop bar so that it does not touch the interposers. The spring bail must not interfere with the .005" to .008" clearance between the interposers and the punch bail tongue. Check this with the interposers in both their normal and the extreme downward positions.

To adjust, loosen the spring bail holding screws and move bail as required.

PUNCH MAGNET ARMATURES (Figure 43)

The punch magnet armatures should be so adjusted that when attracted and sealed to their cores, the respective interposers will move 1/8" from the normal position, toward the magnet coils.

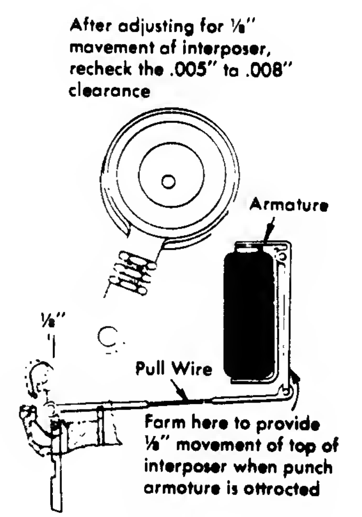


Figure 43. Punch Magnet Armatures Adjustment

1. This adjustment may be checked with the punch bail tongue in position to engage the interposers but may be more accurately checked with the punch bail removed.

2. Hold the armature attracted and check for the 1/8" movement by measuring the distance the operated interposer has moved from an adjacent normally positioned interposer.

3. Obtain the 1/8" movement by increasing or decreasing the armature-core air gap by bending the armature just above the point where the pull wire connects. Use two screwdrivers in making the adjustment; one to support the armature, the other to bend it.

4. Adjust all armatures to move freely and line up evenly in the normal position. Recheck for the .005" to .008" clearance between the interposers and punch bail tongue.

Die Lifter (Figure 44)

The die lifter stop screw provides a positive stop for the die lifter and prevents springing the magnet unit support blocks when leverage is applied from the lifter handle.

With the die in its latched position and the die lifter held against the die latch handles, adjust the stop screw for .010" clearance between the screw end and the side frame.

Vertical Registration (Figure 45)

Cards must be punched in proper alignment, both horizontally and vertically, as determined through the use of the card registration gage.

Horizontal alignment is discussed under Punch Magazine Side Plates.

Vertical punching alignment is obtained by positioning the punch mag-

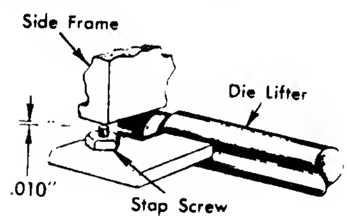


Figure 44. Die Lifter Adjustment

net unit, right or left, as required, relative to the card magazine.

1. With the card magazine half full of cards, punch several cards, check the registration and determine direction (if any) magnet unit must be moved.

2. Loosen the four magnet unit mounting screws and adjust the two aligning screws to position the magnet unit assembly, right or left to obtain correct vertical punching registration. Move the two aligning screws evenly and only when the mounting screws

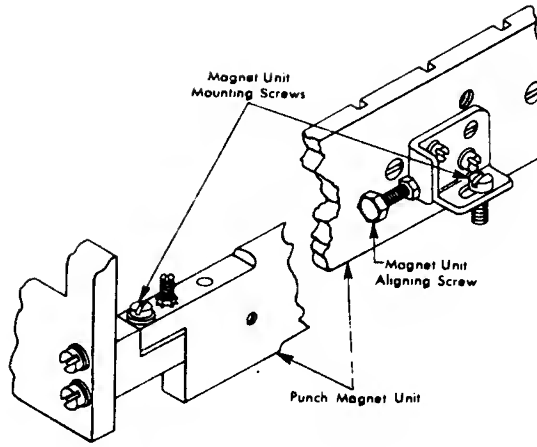


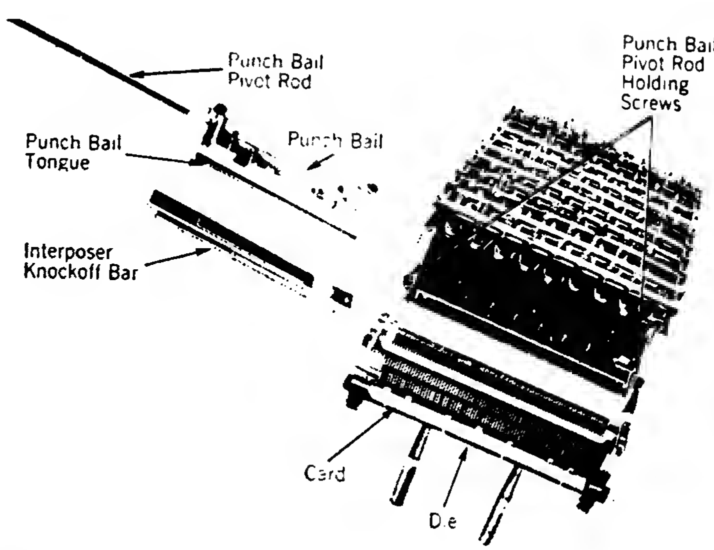
Figure 45. Vertical Registration Adjustment

are loosened, to prevent straining the unit and affecting horizontal registration.

3. Be sure the aligning screw heads are positioned against the castings. Tighten the aligning and mounting screws securely.

4. Recheck for the .003" clearance between the interposers and the punch bail tongue with the punch bail at its upper limit. If required, re-adjust the punch bail connecting links to obtain this clearance. Repositioning the magnet unit always affects this clearance.

Note: Perfect vertical punching alignment should be obtained in the above manner, when card magazine is half full of cards. Slight variations in vertical alignment will result when magazine is either nearly empty or completely filled.

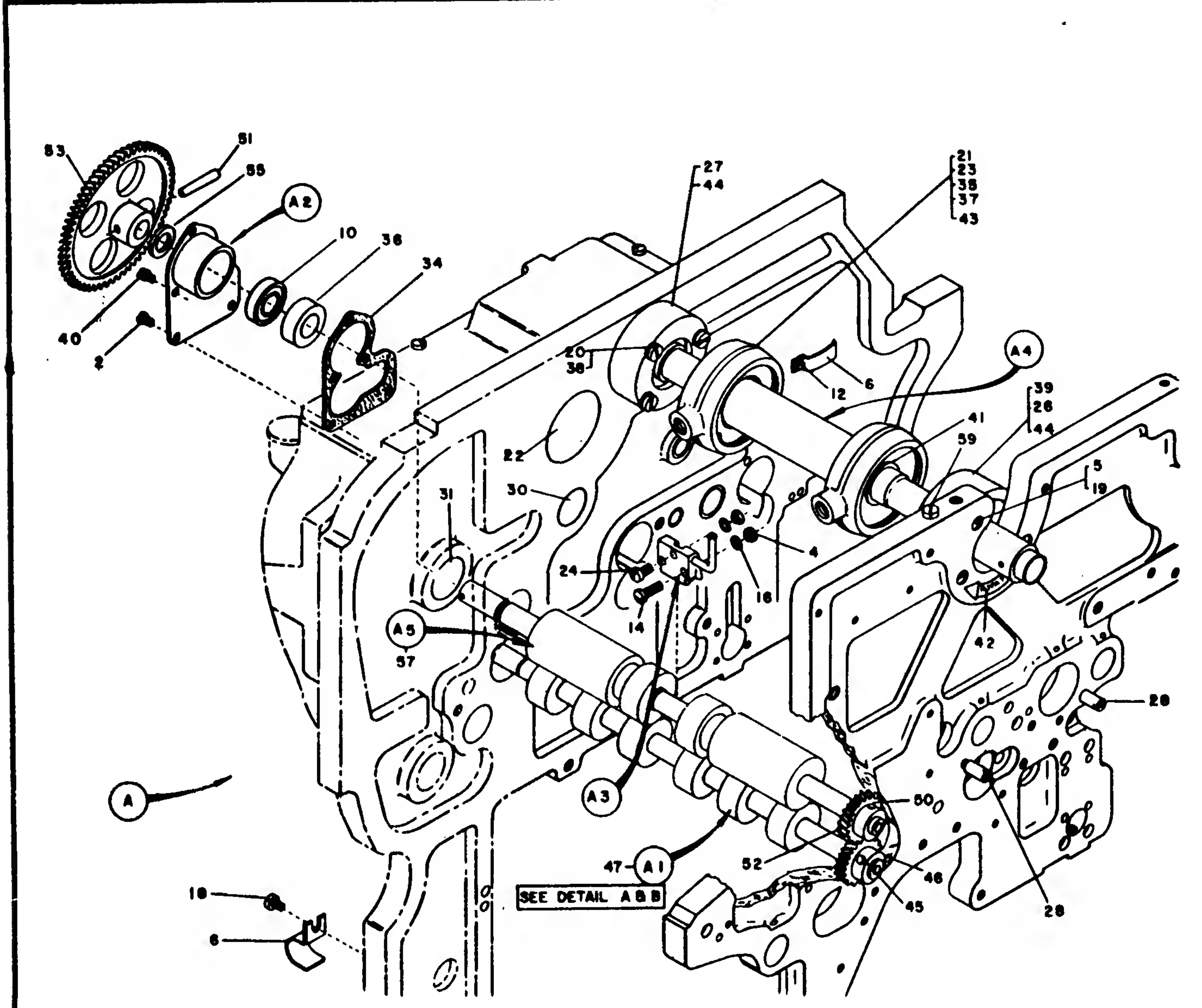


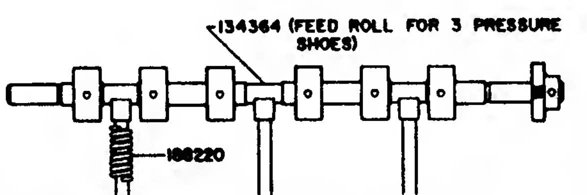
I.B.M. (B)

APPENDIX IV

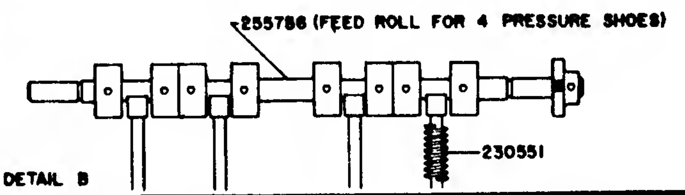
Some Drawings and Dimensions of the 514 Punch

ECCENTRIC SHAFT & 1ST FEED ROLLS - PUNCH FEED





DETAIL A

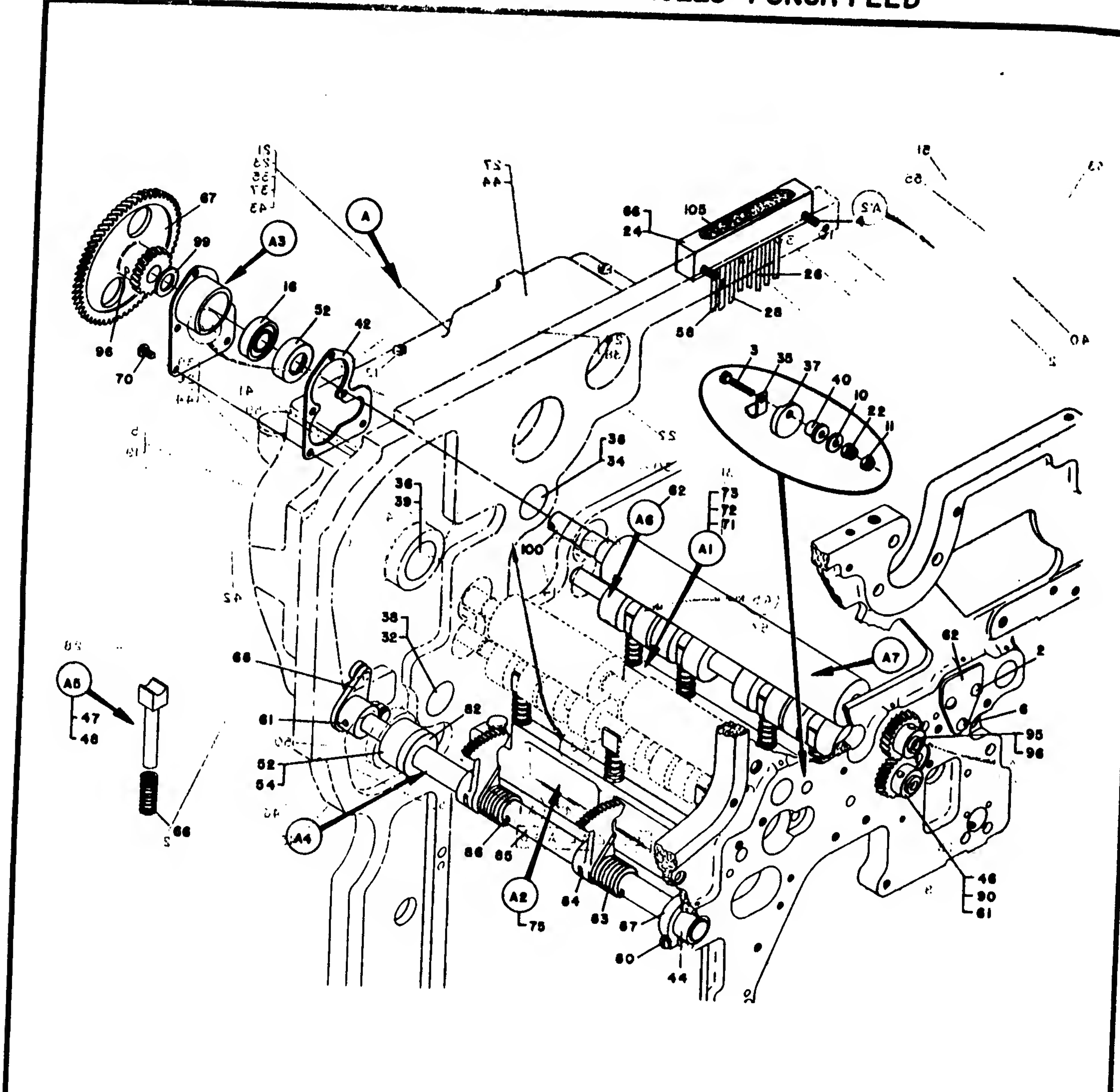


DETAIL B

✠ A	[illegible]	PUNCH FEED UNIT ASSEMBLY [illegible]
✠ A	[illegible]	PUNCH FEED UNIT ASSEMBLY [illegible]
2	[illegible]	SCREW - FEED ROLL END PLATE
4	[illegible]	NUT - FEED ROLL PRESSURE SHOE
5	[illegible]	LWSR - BEARING CAP - FRONT
6	[illegible]	CLAMP - OIL PIPE
8	[illegible]	CLAMP - GEAR CASE DRAIN HOSE
10	[illegible]	BEARING - FEED ROLL
12	[illegible]	SCREW & WASHER - OIL PIPE CLAMP
14	[illegible]	SCREW - FEED ROLL PRESSURE SHOE
16	[illegible]	WASHER - FEED ROLL PRESSURE SHOE
18	[illegible]	SCREW - DRAIN HOSE CLAMP
19	[illegible]	SCREW - BEARING CAP FRONT
20	[illegible]	LWSR - SHAFT RETAINER
21	[illegible]	BEARING - SHAFT ROLLER
22	[illegible]	PLUG - DRIVE PULLEY SHAFT WELCH
23	[illegible]	WASHER - SHAFT BEARING
24	[illegible]	SCREW - FEED ROLL PRESSURE
26	[illegible]	CAP - FRONT SHAFT BEARING
27	[illegible]	CAP - BEARING RETAINING
28	[illegible]	STUD - FEED ROLL GEAR GUARD
30	[illegible]	PLUG - GENEVA SHAFT WELCH
31	[illegible]	PLUG - INNER SHAFT WELCH
34	[illegible]	GASKET - FEED ROLL END PLATE
35	[illegible]	HOUSING - BEARING
36	[illegible]	SEAL - FEED ROLL OIL
37	[illegible]	RING - BEARING LOCK
38	[illegible]	SCREW - BEARING
39	256173	"O" RING
40	[illegible]	SCREW & WASHER - END PLATE
41	[illegible]	RING - BEARING RETAINING
42	[illegible]	DECAL - ROTATION
43	[illegible]	RING - BEARING LOCK
44	[illegible]	BEARING - SHAFT
A1	134364	SHAFT ASM - 1ST LWR FD ROLL (3 PRESS)
A1	255786	SHAFT ASM - 1ST LWR FD ROLL (4 PRESS)
45	[illegible]	PIN - TAPER (USED ON 134364 ONLY)
45	[illegible]	PIN - TAPER (USED ON 255786 ONLY)
✠ 46	[illegible]	GEAR - FEED ROLL
✠ 47	[illegible]	SHAFT - FEED ROLL (USED ON 134364 ONLY)
✠ 47	[illegible]	SHAFT - FEED ROLL (USED ON 255786 ONLY)
A2	[illegible]	PLATE ASM - FEED ROLL END
A3	[illegible]	SHOE ASM - 1ST UPPER FEED ROLL
A4	[illegible]	SHAFT ASM - BEARING & ECCENTRIC
A5	[illegible]	SHAFT ASM - 1ST UPPER FEED ROLL
50	[illegible]	PIN
51	[illegible]	PIN
✠ 52	[illegible]	GEAR - SMALL FEED ROLL
✠ 53	[illegible]	GEAR - FEED ROLL DRIVE
55	[illegible]	SPACER
✠ 57	[illegible]	SHAFT
59	[illegible]	SCREW - SHIELD MTG

✠ NOT RECOMMENDED FOR NORMAL FIELD REPLACEMENT.

PICKER SHAFT & 2ND FEED ROLLS - PUNCH FEED



Ref.	Part No.	Description
★ A	[illegible]	PUNCH FEED UNIT ASSEMBLY (514)
★ A	[illegible]	PUNCH FEED UNIT ASSEMBLY (519)
2	[illegible]	SCREW - BEARING RETAINER
3	[illegible]	SCREW
4	[illegible]	SCREW - OIL RESERVOIR BLOCK
5	[illegible]	SCREW - RETAINING PLATE
10	[illegible]	WASHER
11	7341	NUT
16	[illegible]	BEARING - FEED ROLL
22	[illegible]	NUT
24	[illegible]	BLOCK - OIL RESERVOIR
26	[illegible]	TUBE - 3RD LOWER
28	[illegible]	TUBE - 2ND LOWER
32	[illegible]	BUSHING - CAM SHAFT
34	[illegible]	BEARING - GENEVA SHAFT
35	[illegible]	SPRING - X BRUSH BAR
36	[illegible]	BEARING - DRIVE SHAFT
37	[illegible]	BASE - SPRING
38	[illegible]	PLUG - GENEVA SHAFT WELCH
39	[illegible]	PLUG - DRIVE SHAFT
40	[illegible]	INSULATOR - SPRING
42	[illegible]	GASKET - FEED ROLL END PLATE
44	[illegible]	BUSHING - PICKER SHAFT
46	[illegible]	SPACER - FEED ROLL GEAR
47	[illegible]	SPRING - WICK
48	[illegible]	WICK
52	[illegible]	SEAL
54	[illegible]	BUSHING - PICKER SHAFT
58	[illegible]	TUBE - 1ST LOWER
62	[illegible]	RETAINER - BEARING
66	[illegible]	PLUG - OIL RESERVOIR
68	[illegible]	SPRING - PRESSURE SHOE
70	[illegible]	SCREW & LWSR - END PLATE
A1	[illegible]	BRACKET ASM - FEED ROLL PRESSURE
71	[illegible]	BRACKET - PRESSURE
72	[illegible]	PLUG - OIL
73	[illegible]	CUP - OIL
A2	[illegible]	BRACKET ASM - FEED ROLL PRESSURE
75	[illegible]	BRACKET - PRESSURE
		(BALANCE OF PARTS SHOWN UNDER A1)
A3	[illegible]	PLATE ASM - FEED ROLL END
A4	[illegible]	SHAFT ASM - CARD PICKER
80	[illegible]	SCREW - COLLAR
81	[illegible]	TAPER - PIN
82	[illegible]	SPACER
83	[illegible]	SPRING - SECTOR
84	[illegible]	SECTOR - PICKER SHAFT
85	[illegible]	SHAFT - CARD PICKER
86	[illegible]	ARM - CARD PICKER CAM
87	[illegible]	COLLAR - SHAFT
88	[illegible]	PIN - SHAFT
A5	[illegible]	SHOE ASM - PRESSURE
A6	[illegible]	SHAFT ASM - 2ND LOWER FEED ROLL
90	[illegible]	TAPER PIN
★ 91	[illegible]	GEAR
★ 92	[illegible]	SHAFT - 2ND LOWER FEED ROLL
A7	[illegible]	SHAFT ASM - 2ND UPPER FEED ROLL
[illegible]	[illegible]	TAPER PIN
[illegible]	[illegible]	TAPER PIN
★ [illegible]	[illegible]	GEAR
★ [illegible]	[illegible]	GEAR
99	[illegible]	SPACER
★ 100	[illegible]	SHAFT - 2ND ROLL 2ND UPPER

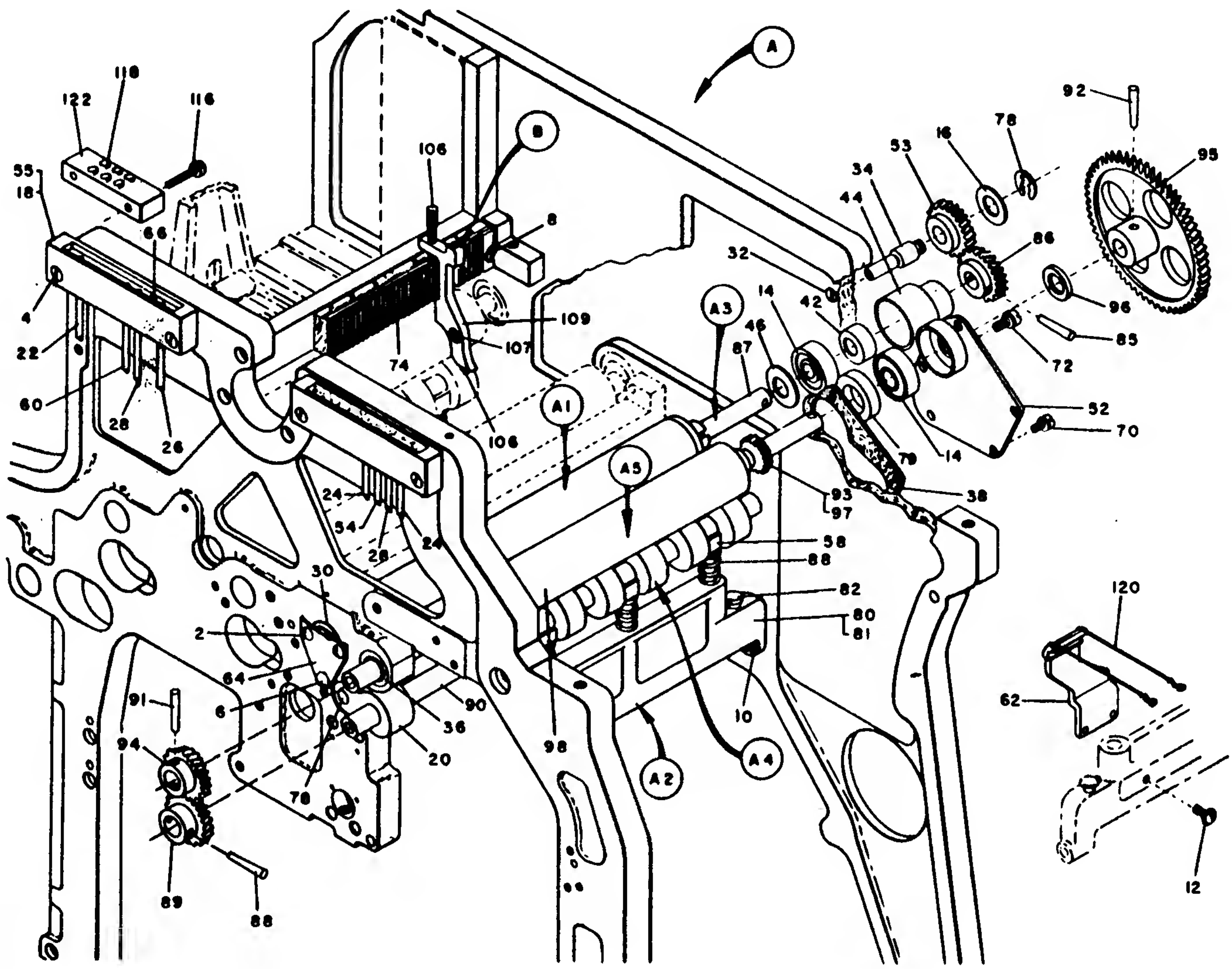
PARTS NOT INCLUDED WITH ASSEMBLIES

Ref.	Part No.	Description
105	[illegible]	FELT - OIL

★ NOT RECOMMENDED FOR NORMAL FIELD REPLACEMENT.

PRINTED IN U.S.A
MARCH 1, 1962

"X" BRUSH & CONTACT ROLL & 3RD FEED ROLL ASMS – PUNCH FEED



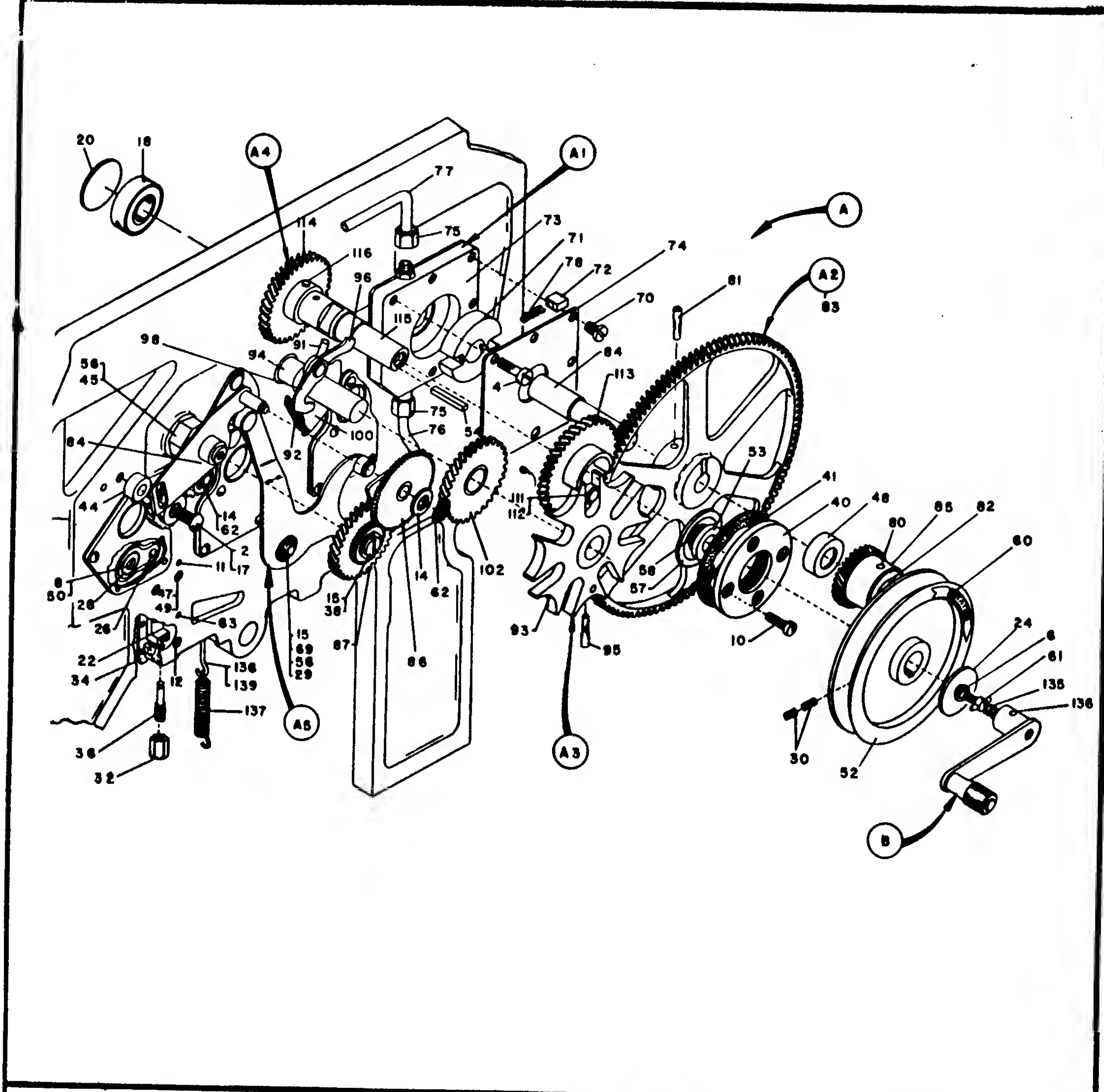
A	601781	PUNCH FEED UNIT ASM (514)
A	601780	PUNCH FEED UNIT ASM (519)
2	72	SCREW - BEARING RETAINING
4	232	SCREW - RESERVOIR MOUNTING (LONG)
6	424	SCREW - PLATE RETAINING
8	1451	SCREW - R BRUSH HOLDER BAR
10	3607	SCREW - PRESSURE BRACKET PIVOT
12	601741	SCREW - SPRING ANCHOR (519 ONLY)
14	22678	BEARING - CONTACT ROLL
16	24091	WASHER
18	121070	BLOCK - OIL RESERVOIR
20	121571	BEARING - FEED ROLL
22	121404	TUBE - OIL
24	121400	TUBE - OIL
26	121474	TUBE - OIL
28	121483	TUBE - OIL
30	[illegible]	BEARING - CONTACT ROLL
32	[illegible]	SCREW
34	[illegible]	STUD
36	[illegible]	BUSHING - FEED ROLL FRONT
38	133572	GASKET - END PLATE
42	133959	SEAL - OIL
44	133967	BUSHING
46	[illegible]	GUARD - BEARING DUST
52	134081	END PLATE
53	134193	GEAR - CAM
54	134039	TUBE - OIL
55	[illegible]	SCREW - MOUNTING (SHORT)
58	[illegible]	SHOE - FEED ROLL PRESSURE
60	[illegible]	TUBE - OIL
62	193120	ANCHOR - CARD GUIDE SPRING (519 ONLY)
64	[illegible]	RETAINER
66	[illegible]	PLUG - RESERVOIR
68	[illegible]	SPRING - PRESSURE SHOE
70	[illegible]	SCREW - END PLATE
72	[illegible]	SCREW - END PLATE
74	[illegible]	BAR - R BRUSH HOLDER
76	[illegible]	SPRING CLIP
78	[illegible]	STUD - BEARING
79	133927	SEAL - OIL
A1	[illegible]	CONTACT ROLL ASM
A2	[illegible]	BRACKET ASM - FEED ROLL PRESSURE
80	[illegible]	BRACKET
81	[illegible]	PLUG - OIL CHAMBER
82	[illegible]	OIL CUP
A3	[illegible]	SHAFT ASM - CONTACT ROLL DRIVE
85	8427	PIN - TAPER
86	[illegible]	GEAR - CONTACT ROLL
87	[illegible]	SHAFT - CONTACT ROLL DRIVE
A4	[illegible]	ROLL ASM - 3RD LOWER FEED
88	[illegible]	TAPER PIN
89	[illegible]	GEAR
90	[illegible]	SHAFT - FEED ROLL
A5	[illegible]	FEED ROLL ASM - UPPER (514)
A5	[illegible]	FEED ROLL ASM - UPPER (519)
91	[illegible]	TAPER PIN
92	[illegible]	TAPER PIN
93	8427	TAPER PIN (514 ONLY)
94	[illegible]	GEAR - FEED ROLL
95	[illegible]	GEAR - FEED ROLL
96	[illegible]	COLLAR - BEARING
97	[illegible]	GEAR - STACKER DRIVE (514 ONLY)
98	193134	FEED ROLL
B	257567	HOLDER ASM - X BRUSH
106	133147	SCREW - THUMB
107	[illegible]	SCREW - BRUSH MOUNTING
108	[illegible]	R BRUSH
109	[illegible]	HOLDER - R BRUSH

PARTS NOT INCLUDED WITH ASSEMBLIES

116	[illegible]	SCREW - TERMINAL BLOCK
118	[illegible]	SLEEVE
120	[illegible]	GUIDE - CARD (519 ONLY)
122	[illegible]	BLOCK - TERMINAL

NOT RECOMMENDED FOR NORMAL FIELD REPLACEMENT

DRIVE PULLEY & GENEVA CLUTCH GEAR ASMS



◆	A	001701	PUNCH FEED UNIT ASM (514)
◆	A	001701	PUNCH FEED UNIT ASM (519)
	2	304	SCREW - CAM AND GEAR BRACKET
	4	3077	SCREW - OIL PUMP MOUNTING
	6	[illegible]	LWSR - CRANK STUD
	5	13119	WASHER - FEED ROLL BEARING
	10	[illegible]	SCREW - BEARING RETAINER
	11	[illegible]	PIN - BRUSH SLIDE UPPER
	12	24019	SCREW - SLIDE GUIDE
	14	[illegible]	WASHER - RETAINING
	15	[illegible]	WASHER - RETAINING
	17	[illegible]	WASHER
	18	[illegible]	BEARING - DRIVE SHAFT
	20	[illegible]	PLUG - DRIVE PULLEY WELCH
	22	[illegible]	PLATE - BRUSH SLIDE ADJUSTING
	24	[illegible]	WASHER - CRANK STUD
	26	[illegible]	STUD - FEED BEARING
	28	[illegible]	BEARING - FEED ROLL
	29	[illegible]	STUD - ROLL MOUNTING
	30	[illegible]	SCREW - PULLEY SET
	32	[illegible]	NUT - BRUSH SLIDE ADJUSTING
	34	[illegible]	GUIDE - BRUSH SLIDE
	36	[illegible]	SCREW - BRUSH SLIDE ADJUSTING
	38	[illegible]	SCREW - IDLER GEAR
	40	173025	RETAINER - BEARING
	41	173026	GASKET - RETAINER
	44	[illegible]	SPACER - BRACKET
	45	[illegible]	STUD - CAM & GEAR ARM
	47	[illegible]	WASHER - SLIDE GUIDE
	48	[illegible]	OIL SEAL
	49	[illegible]	PACKING - CARD GUIDE SCREW
	50	[illegible]	SCREW - FEED ROLL THRUST
	52	[illegible]	PULLEY - DRIVE
	53	[illegible]	SPACER - PULLEY
	54	[illegible]	KEY - DRIVE PULLEY
	56	[illegible]	SCREW - ARM STUD
	57	[illegible]	WASHER - OIL RETAINING
	58	[illegible]	"O" RING
	60	[illegible]	DECAL - ROTATION
	61	[illegible]	STUD - CRANK
	62	[illegible]	CLIP - RETAINING SPRING
	63	[illegible]	PIN - BRUSH SLIDE LOWER
	64	[illegible]	BRACKET - CAM GEAR
	66	[illegible]	GEAR - CLUTCH CAM
	67	[illegible]	GEAR - FEED ROLL [illegible]
	69	[illegible]	CLIP - SPRING
	A1	[illegible]	PUMP ASM - OIL
	70	[illegible]	SCREW - SIDE PLATE
	71	[illegible]	ROTOR - OIL PUMP
	72	[illegible]	VANE - OIL PUMP
	73	[illegible]	HOUSING - OIL PUMP
	74	[illegible]	PLATE - OIL PUMP
	75	[illegible]	CONNECTOR - OIL PUMP
	76	[illegible]	TUBE - LOWER OIL
	77	[illegible]	TUBE - UPPER OIL
	78	[illegible]	SPRING - OIL PUMP VANE
	A2	[illegible]	SHAFT ASM - IDLER GEAR
	80	[illegible]	PIN - GEAR TAPER
	81	[illegible]	PIN - GEAR TAPER
	82	[illegible]	PLUG - DRIVE GEAR
◆	83	[illegible]	GEAR - CLUTCH IDLER
◆	84	[illegible]	SHAFT - IDLER GEAR
◆	85	[illegible]	GEAR - CLUTCH DRIVE
	A3	[illegible]	CLUTCH ASM - GENEVA
	91	[illegible]	PIN - TAPER
	92	[illegible]	SPRING - DOG
◆	93	[illegible]	DISC - INTERMITTENT
◆	94	[illegible]	SHAFT - GENEVA WHEEL
	95	[illegible]	PIN - TAPER
	98	100114	DOG - DRIVE
	99	100117	DOG - DETENT
◆	100	100121	ARM - DOG
◆	102	[illegible]	GEAR
	A4	221740	SHAFT ASM - DRIVE
◆	111	173019	STUD - ROLLER
◆	112	173020	ROLLER - GEAR
◆	113	[illegible]	GEAR - DRIVE
◆	114	[illegible]	GEAR - ECCENTRIC DRIVE
◆	115	[illegible]	SHAFT - DRIVE PULLEY
	116	257971	PIN - GEAR TAPER
	A5	[illegible]	ARM ASM - LATCH CAM ROLLER
	B	[illegible]	CRANK ASM - HAND
	135	[illegible]	SPRING - CRANK RELEASE
	136	[illegible]	PIN - SPRING RETAINING

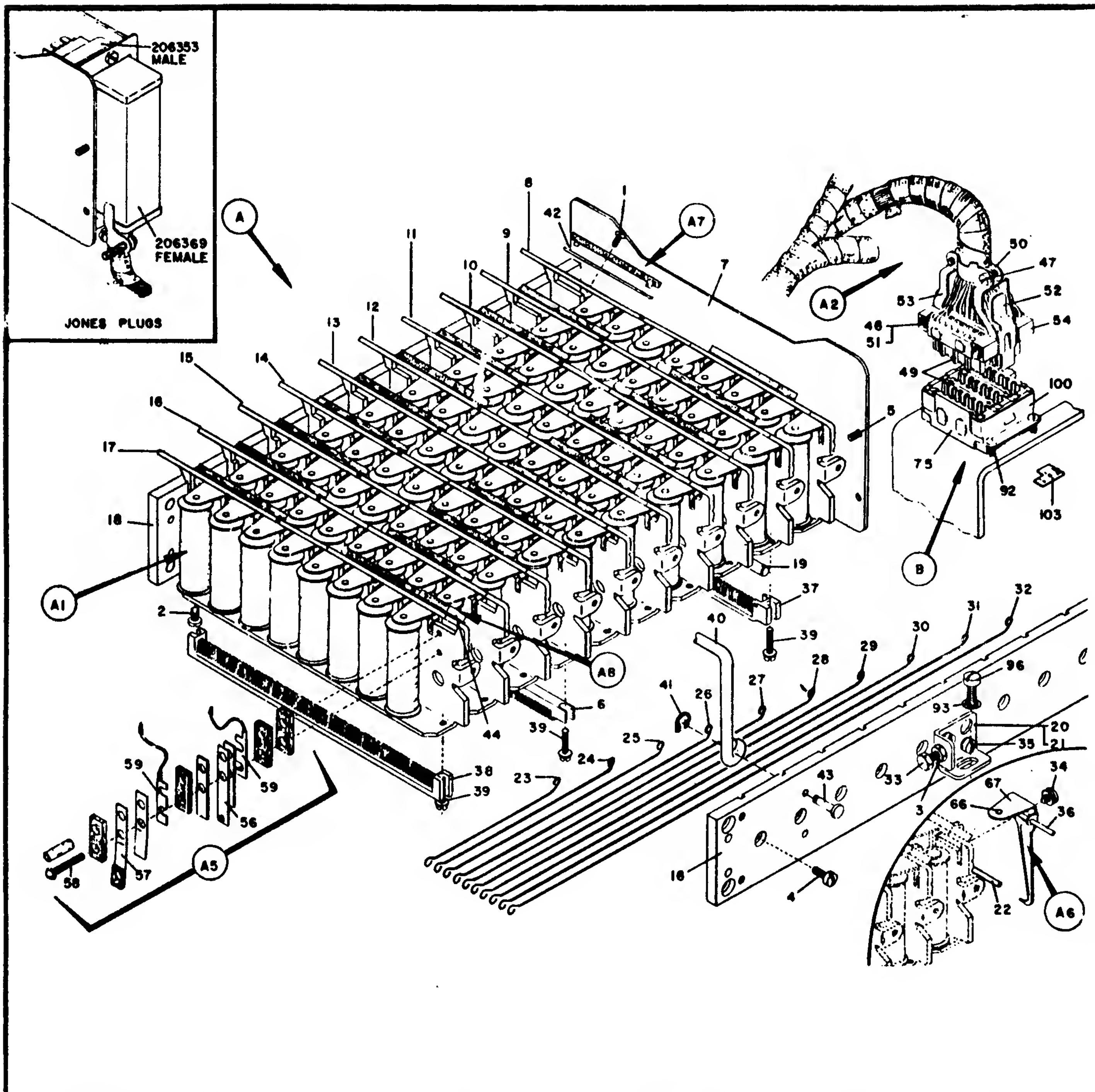
PARTS NOT INCLUDED WITH ASSEMBLIES

137	[illegible]	SPRING - EXTENSION
138	[illegible]	HOOK - SPRING ANCHOR
139	[illegible]	NUT

◆ NOT RECOMMENDED FOR NORMAL FIELD REPLACEMENT.

PRINTED IN U.S.A.
[illegible] 1, [illegible]

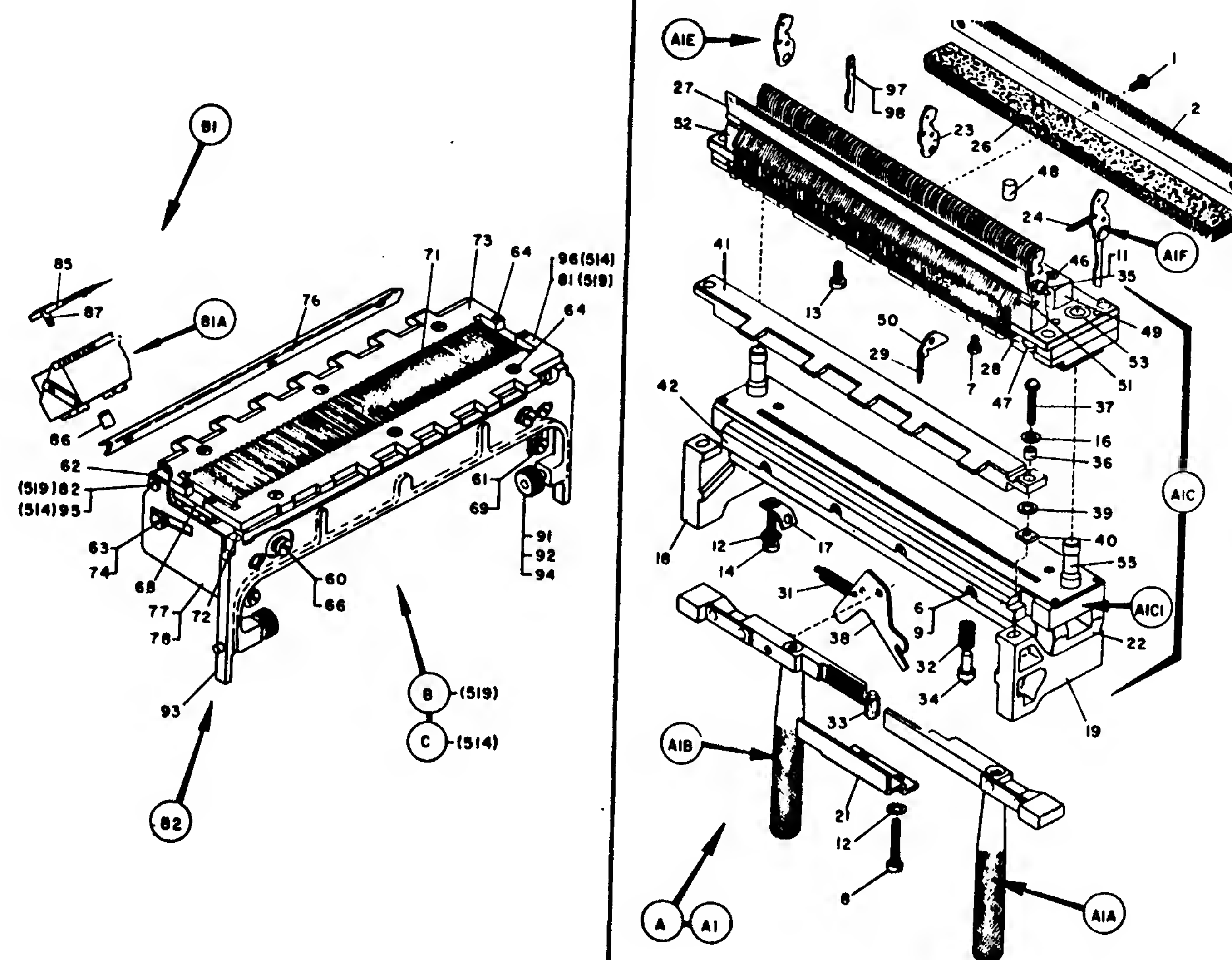
MAGNET UNIT ASM VIEW I



A	122503	MAGNET UNIT ASM (519)
A	100621	MAGNET UNIT ASM NL 5.1
1	106	SCREW - TERMINAL BLOCK MOUNTING
2	337	SCREW - MAGNET MOUNTING
3	6700	NUT - LOCK
4	23012	SCREW - PLATE LOCKING
5	34512	SCREW - BACK PLATE
6	105362	GUIDE - INTERPOSER PAWL LINK
7	111563	PLATE - MAGNET UNIT BACK
✱ 8	111751	PLATE - MAGNET MTG NO. 1
✱ 9	111756	PLATE - MAGNET MTG NO. 2
✱ 10	111751	PLATE - MAGNET MTG NO. 3
✱ 11	122505	PLATE - MAGNET MTG NO. 4
✱ 12	111745	PLATE - MAGNET MTG NO. 5
✱ 13	111740	PLATE - MAGNET MTG NO. 6
✱ 14	111738	PLATE - MAGNET MTG NO. 7
✱ 15	111695	PLATE - MAGNET MTG NO. 8
✱ 16	111677	PLATE - MAGNET MTG NO. 9
✱ 17	111676	PLATE - MAGNET MTG NO. 10
18	173040	PLATE - MAGNET UNIT 5158
19	173080	SUPPORT - INTERPOSER PAWL LINK
20	173077	BRACKET - MAGNET UNIT SUPPORT FRONT
21	173078	BRACKET - MAGNET UNIT SUPPORT REAR
22	173786	ROD - ARMATURE SCREW
23	134481	PULL WIRE
24	134482	PULL WIRE
25	134483	PULL WIRE
26	134484	PULL WIRE
27	134485	PULL WIRE
28	134486	PULL WIRE
29	134487	PULL WIRE
30	134488	PULL WIRE
31	134489	PULL WIRE
32	134490	PULL WIRE
33	138658	SCREW - ADJUSTING
34	230730	SCREW & WASHER - ARMATURE SUPPORT
35	234017	SCREW & LWSR - MAGNET BRACKET
36	257064	ROD - ARMATURE PIVOT
37	257272	COMB - PULL WIRE GUIDE
38	257273	COMB - PULL WIRE GUIDE
39	257274	SCREW & WASHER - GUIDE COMB
40	257680	HANDLE - MAGNET UNIT
41	257706	CLIP - PIN HANDLE MOUNTING
42	302135	BLOCK - MOUNTING
43	459624	PIN -
44	600997	INSULATION - STRIP
A1	111251	COIL ASM - SCREW AND MAGNET
A2	122770	CABLE ASM
47	345	SCREW
48	97524	CLIP
49	122610	CLIP
50	257737	CLAMP
51	257738	STUD
52	257740	CLIP
53	257742	SUPPORT
54	257744	BLOCK - MALE TERMINAL
A5	134679	CONTACT ASM - KNOCKOFF BAR
56	8740	SPRING - CONTACT
57	[illegible]	SPRING - CONTACT
58	173087	SCREW - CONTACT MOUNTING
59	601689	TERMINAL - CONTACT
A6	149649	ARMATURE ASM MAGNET
66	117089	RESIDUAL ARMATURE
✱ 67	173095	ARMATURE - MAGNET
A7	300090	BLOCK ASM - TERMINAL
A8	600996	BLOCK ASM - TERMINAL
B	111400	CABLE ASM (514)
B	111592	CABLE ASM (519)
75	257240	BLOCK - FEMALE TERMINAL
PARTS NOT INCLUDED WITH ASSEMBLIES		
92	2346	SCREW - MTG BRACKET
93	30125	LOCKWASHER - MAGNET UNIT MTG
96	173995	SCREW - MAGNET UNIT MTG
100	257248	BRACKET - MOUNTING
103	600195	NUMBER PLATE

✱ NOT RECOMMENDED FOR NORMAL FIELD REPLACEMENT.

PUNCH BRUSH SLIDE & PUNCH DIE & STRIPPER (STD) VIEW III



Ref.	Part No.	Description
A	[illegible]	MAGNET UNIT ASM
B	[illegible]	MAGNET UNIT ASM - MARK SENSING
1	[illegible]	SCREW - LINK GUIDE MOUNTING
2	133714	GUIDE - FRONT LINK
B1	[illegible]	PUNCH DIE AND STRIPPER ASM
6	[illegible]	WASHER - DIE CARD GUIDE
7	[illegible]	SCREW - PUNCH GUIDE
8	2304	SCREW - LOCK RACK COVER
9	[illegible]	SCREW - DIE CARD GUIDE MOUNT
11	4736	SCREW - GUIDE INTERPOSER PAWL
12	6315	LWSR
13	[illegible]	SCREW - INTER PAWL LOCK BAR
14	30376	SCREW - BLOCK MOUNTING
16	[illegible]	INSULATION - CONTACT BAR SCREW
17	[illegible]	SPRING - LOCK RACK
18	[illegible]	BRACKET - M. S. BRUSH HOLDER REAR
19	[illegible]	BRACKET - M. S. BRUSH HOLDER FRONT
21	112611	COVER - SLIDE LOCK RACK
22	112613	BLOCK - DIE PLATE [illegible]
23	[illegible]	PAWL - INTERPOSER
24	[illegible]	SPRING - SLIDE PAWL
26	[illegible]	FELT - LUBRICATING
27	[illegible]	ANCHOR - INTERPOSER SPRING
28	[illegible]	BAR - PUNCH STOP
29	[illegible]	SPRING - PAWL STOP
31	[illegible]	SPRING - INTERPOSER
32	[illegible]	SPRING - DIE RELEASE PIN
33	151911	PINION - SLIDE LOCK RACK
34	151914	PIN - DIE RELEASE
35	[illegible]	LWSR - GUIDE SCREW
36	[illegible]	INSULATION - X BRUSH CONTACT
37	[illegible]	SCREW - X BRUSH CONTACT BAR
38	[illegible]	INTERPOSER - DIE LOCK
39	[illegible]	SPACER - X BRUSH CONTACT BAR
40	[illegible]	NUT - X BRUSH CONTACT BAR
41	209115	BAR - X BRUSH CONTACT
42	[illegible]	GUIDE - CARD
A1A	[illegible]	RATCHET ASM - SLIDE LOCK FRONT
A1B	[illegible]	RATCHET ASM - SLIDE LOCK REAR
A1C	[illegible]	DIE SUB ASM - PUNCH
46	[illegible]	SCREW - GUIDE BAR
47	[illegible]	SCREW - LOCK BAR
48	[illegible]	PIN - DOWEL
49	[illegible]	GUIDE BAR - INTERPOSER
50	[illegible]	STOP - INTERPOSER PAWL
51	[illegible]	SHAFT - STOP PIVOT
52	[illegible]	BAR - PLATE LOCK
53	[illegible]	BUSHING - DIE GUIDE
A1C1	[illegible]	PLATE ASM - DIE
55	[illegible]	STUD - DIE GUIDE
A1E	[illegible]	PAWL ASM - INTERPOSER
A1F	[illegible]	PUNCH ASM - INTERPOSER PAWL
B	[illegible]	SLIDE ASM - CARD GUIDE (519)
60	273	SCREW - CARD GUIDE SLIDE
61	[illegible]	NUT - BRUSH HOLDER SUPPORT
62	[illegible]	BAR - FRONT CARD GUIDE SUPPORT
63	[illegible]	WASHER - BRUSH HOLDER
64	[illegible]	SCREW
66	[illegible]	WASHER - CARD GUIDE SLIDE
68	[illegible]	SPACER - CARD GUIDE
69	[illegible]	SCREW - BRUSH HOLDER SUPPORT
71	[illegible]	SEPARATOR - BRUSH
72	[illegible]	SLIDE - CARD GUIDE
73	[illegible]	GUIDE - FRONT CARD
74	[illegible]	SCREW - BRUSH HOLDER
76	[illegible]	INSULATOR - BRUSH
77	[illegible]	SUPPORT - BRUSH HOLDER LEFT
78	[illegible]	SUPPORT - BRUSH HOLDER RIGHT
81	[illegible]	GUIDE - REAR CARD
82	[illegible]	SCREW - CARD GUIDE SUPPORT
B1	[illegible]	HOLDER ASM - BRUSH
85	[illegible]	BRUSH - CARD READ
86	[illegible]	NUT - BRUSH CLAMPING
87	[illegible]	SCREW - BRUSH CLAMPING
★ B1A	[illegible]	BLOCK ASM - BRUSH HOLDER
B2	[illegible]	SUPPORT ASM - CARD GUIDE
91	[illegible]	PLUNGER - CARD GUIDE
92	[illegible]	SPRING - CARD GUIDE
93	[illegible]	SUPPORT - CARD GUIDE
94	[illegible]	KNOB - PLUNGER
C	[illegible]	SLIDE ASM - CARD GUIDE (514)
95	[illegible]	SCREW
96	[illegible]	GUIDE - REAR CARD
		(BALANCE OF PARTS SHOWN UNDER B)

PARTS NOT INCLUDED WITH ASSEMBLIES

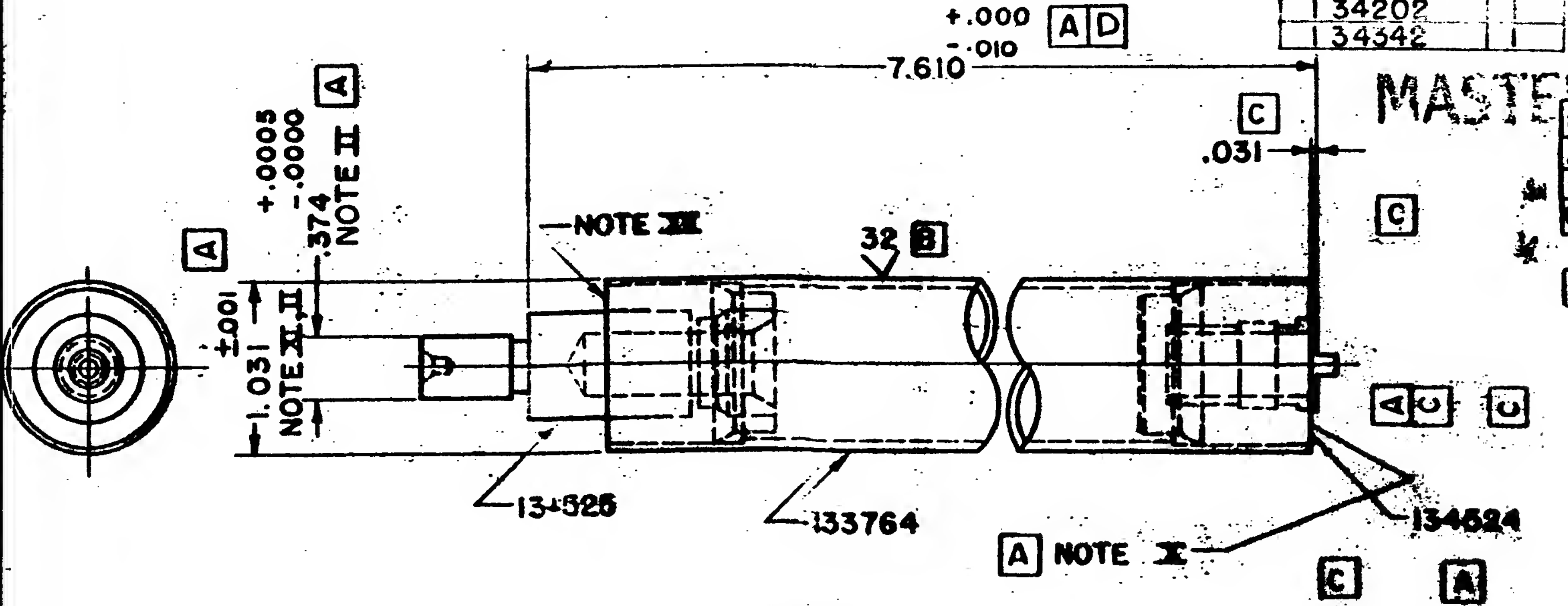
Ref.	Part No.	Description
97	[illegible]	PUNCH
98	[illegible]	PUNCH - OVERSIZE

★ NOT RECOMMENDED FOR NORMAL FIELD REPLACEMENT.

167552	1	
167553	1	
134002	AS REQ	
134202		
134342	1	

SYM	DATE
	SEE IN
	5-21-4[illegible]
	1-17-52
A 11	8-12-5[illegible]
B 1	6-11-56
C 6	10-29-5[illegible]
M	1-9-57
D 1	10-20-5[illegible]

MASTER



NOTES

A X - CONTACT ROLL INSULATION PARTS 134524 AND 1345[illegible] BE FLUSH $^{+.002}_{-.005}$ AGAINST CONTACT ROLL ON BOTH SIDES.

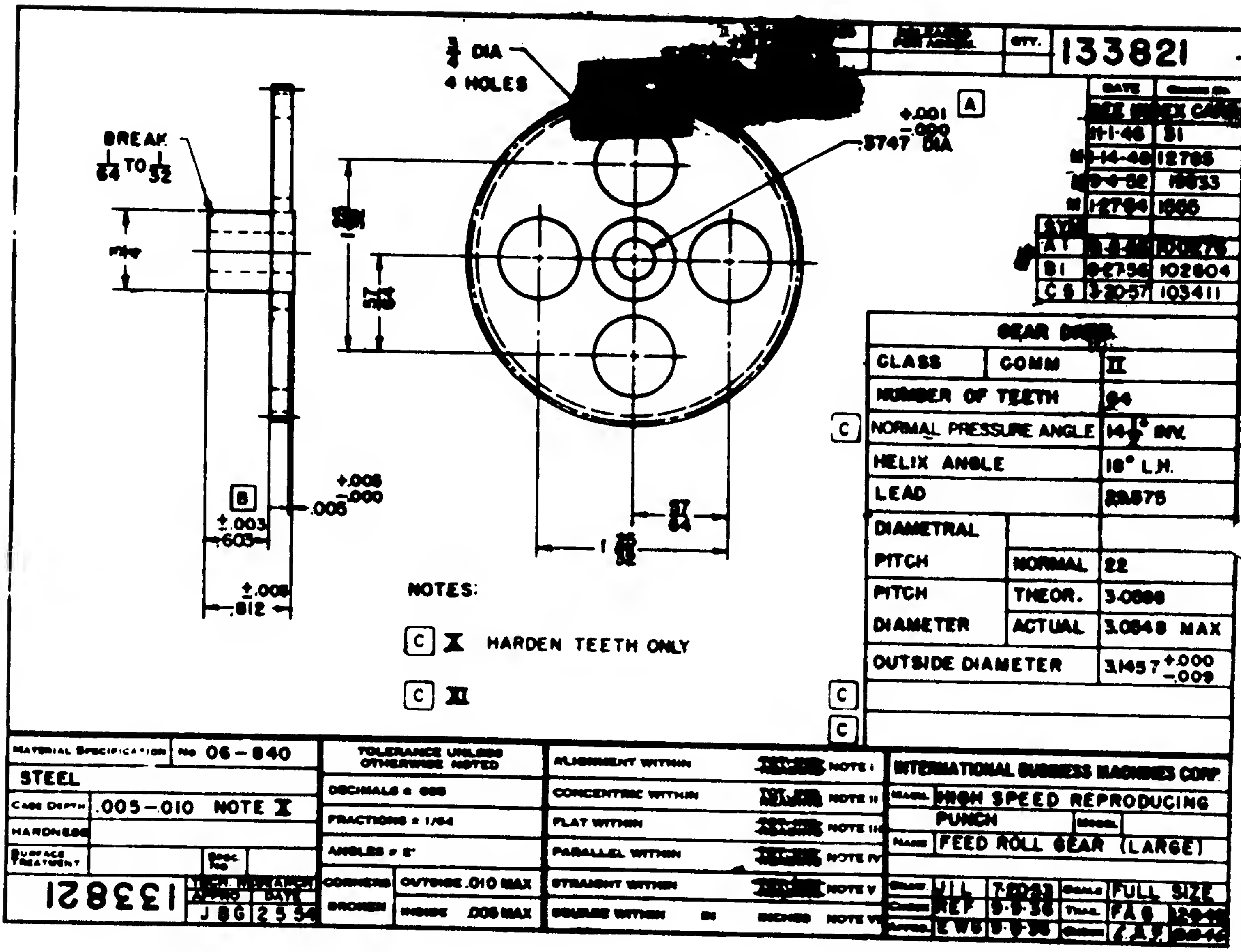
XI - GROOVED ROLLS TO BE GROUND DOWN TO 1.017 DIAM. & STOCKED UNDER 134347.

XII - ROLLS OF 1.017 DIAM. TO BE MARKED WITH RED PAINT ON LEFT FOR IDENTIFICATION.

XIII - SIMILAR TO 221779

MATERIAL SPECIFICATION	No.	TOLERANCE UNLESS OTHERWISE NOTED		ALIGNMENT WITHIN	TOT. IND. READING NOTE I	INTERNATIONAL BUSINESS MAC[illegible]
		DECIMALS ± .005	A	CONCENTRIC WITHIN .005 A	TOT. IND. READING NOTE II	MACH. HIGH SPEED REPRODUC[illegible]
DEPTH		FRACTIONS ± 1/64	A	FLAT WITHIN	TOT. IND. READING NOTE III	MODEL
[illegible]NESS		ANGLES ± 2°		PARALLEL WITHIN	TOT. IND. READING NOTE IV	NAME CONTACT ROLL AS[illegible]
[illegible]	SPEC. No.	CORNERS MAY BE	OUTSIDE	STRAIGHT WITHIN	TOT. IND. READING NOTE V	DRAW H. M. 10.27.37 SCALE FU[illegible]
	TECH. RESEARCH APPRO. DATE					CHECK R. E. F. 3.24.38 TRAC. C [illegible]

2-1-6040

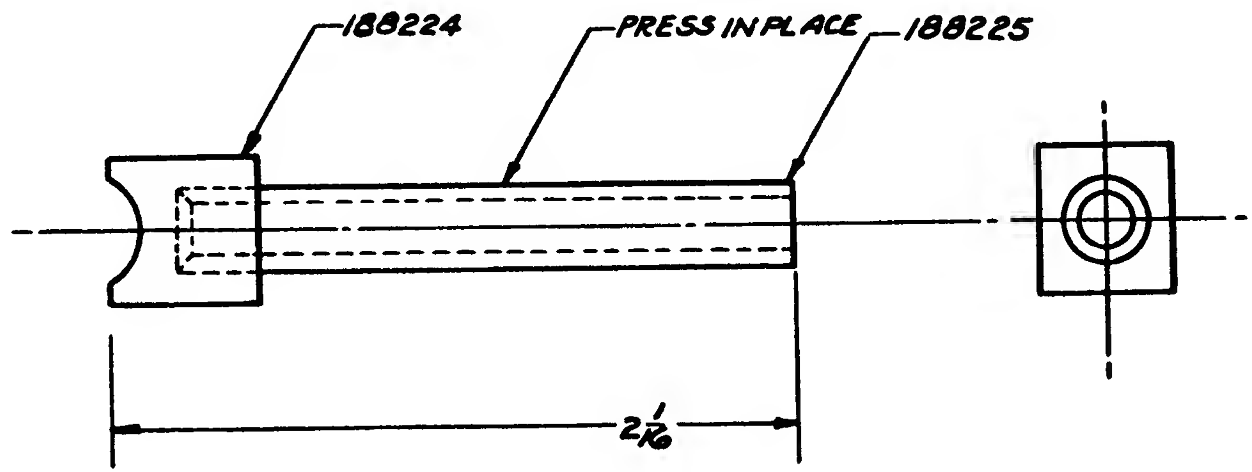


133821
QTY.
DATE
SEE INDEX CARD
$\frac{3}{4}$ DIA
4 HOLES
BREAK $\frac{1}{64}$ TO $\frac{1}{32}$
+.001 −.000 .3747 DIA
+.005 −.000 .005
±.003 .605
±.005 .812
$\frac{57}{64}$
NOTES:
C I HARDEN TEETH ONLY
C II
GEAR DATA
CLASS COMM II
NUMBER OF TEETH 64
NORMAL PRESSURE ANGLE $14\frac{1}{2}°$ INV.
HELIX ANGLE 18° L.H.
DIAMETRAL PITCH NORMAL 22
PITCH DIAMETER THEOR.
PITCH DIAMETER ACTUAL 3.0648 MAX
OUTSIDE DIAMETER 3.1457 +.000 −.009
MATERIAL SPECIFICATION No 06-840
STEEL
CASE DEPTH .005-.010 NOTE I
HARDNESS
SURFACE TREATMENT
TOLERANCE UNLESS OTHERWISE NOTED
FRACTIONS ± 1/64
ANGLES ± 2°
CORNERS OUTSIDE .010 MAX
BROKEN INSIDE .005 MAX
ALIGNMENT WITHIN NOTE I
CONCENTRIC WITHIN NOTE II
FLAT WITHIN NOTE III
PARALLEL WITHIN NOTE IV
STRAIGHT WITHIN NOTE V
SQUARE WITHIN IN INCHES NOTE VI
INTERNATIONAL BUSINESS MACHINES CORP.
HIGH SPEED REPRODUCING PUNCH
FEED ROLL GEAR (LARGE)
SCALE FULL SIZE
133821
J B G

STANDARDS CODE	USED ON ASSEM.	QTY.	
1-5515	184371	11	188226

MASTER

DATE	CHANGE NO.
12-9-41	3930



STEM TO BE AT RIGHT ANGLES WITH BEARING SURFACE WITHIN .005 IN $2\frac{1}{16}$

STANDARD

TOLERANCE ON FRACTIONS $\pm \frac{1}{64}$ UNLESS OTHERWISE NOTED

SPECIFICATIONS			
FINISH		SPEC. NO.	
HEAT TREAT		SPEC. NO.	
MATERIAL			
STOCK SIZE			

MFG ENG ANALYSIS	DATE
TECH RESEARCH	DATE
STOCK PER 100 PCS.	LB. / FT.

INTERNATIONAL BUSINESS MACHINES Corp.

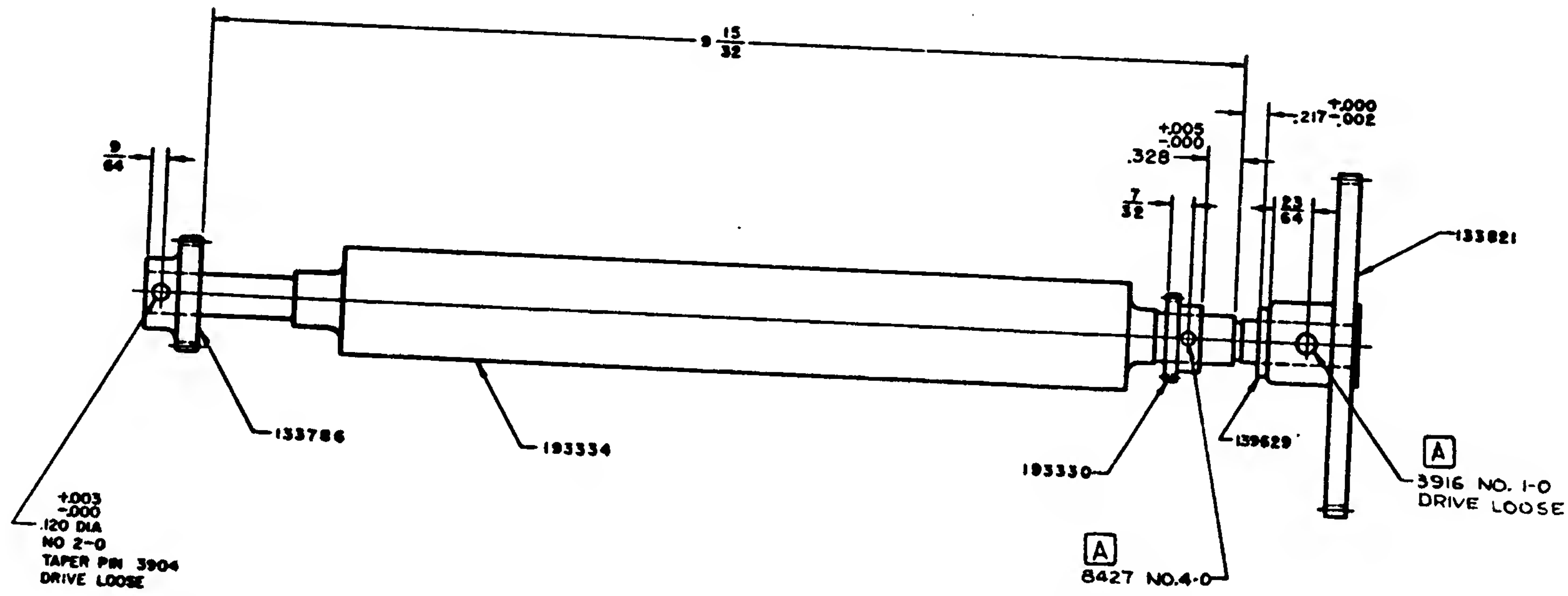
MACH.	GANG SUMMARY PUNCH		
NAME	FEED ROLL PRESSURE SHOE ASSEMBLY.		
MODEL		SCALE	TWICE SIZE
DRAW	HM. 6-3-41	CHECK	BRC. 12-9-41
TRAC.	HM. 8-4-41	APPRO.	JHH "

188226

STANDARDS CODE		QTY	
NONE	184359	1	193333

	DATE	CHANGE NO
M	12-14-43	4749
	6-12-52	19018
	10-4-54	D2358
A	7-10-61	

A2 7-10-61 REMOVED .136 AND .089 DIAMETERS.



NOTE
I SIMILAR TO 134458

TOLERANCE ON FRACTIONS ± 1/64 UNLESS OTHERWISE NOTED

SPECIFICATIONS				
FINISH		SPEC NO		
HEAT TREAT		SPEC NO		
MATERIAL				
STOCK SIZE				

MFG ENG ANALYSIS	DATE
TECH RESEARCH	DATE
STOCK PER 100 PCS	LB
	FT

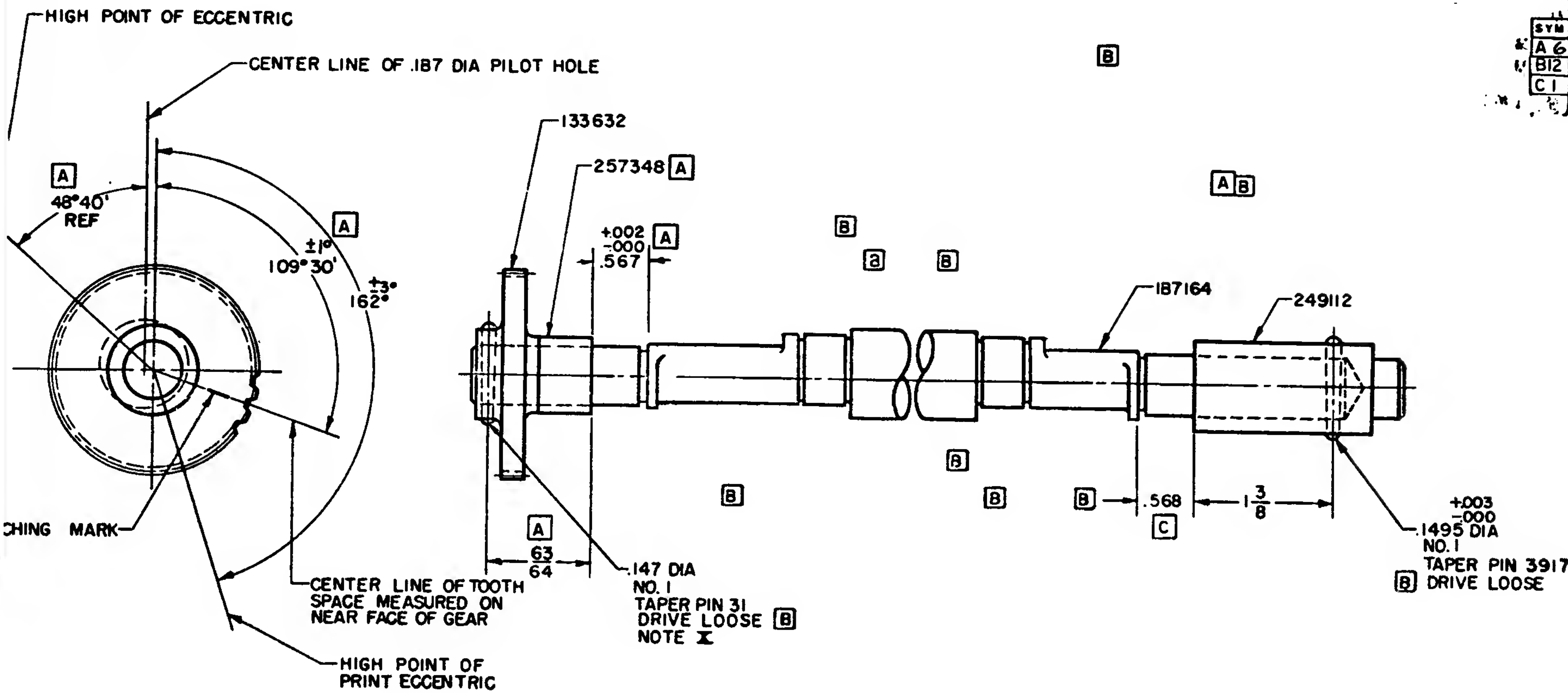
INTERNATIONAL BUSINESS MACHINES Corp

MACH	HIGH SPEED REPRODUCING PUNCH		
NAME	UPPER FEED ROLL		
	SHAFT ASSEMBLY (PUNCH)		
MODEL	513	SCALE	FULL SIZE
DRAW	R. U. 10-20-43	CHECK	
TRAC	E.L.T. 11-22-43	APPRO	

193333

STANDARDS CODE	RELEASED FOR ASSEMBLY	QTY.	187173
NONE	193341	1	

SYM	DATE	CHANGE NO.
	SEE INDEX CARD	
	5-19-52	19611
	8-25-53	D19840
A 6	4-12-55	100135
B12	8-29-56	102232
C 1	10-11-56	D102232
	12-27-56	D102232



NOTE
B I PIN MAY PROJECT 1/8 ON LARGE DIA. END, 1/32 ON SMALL DIA. END

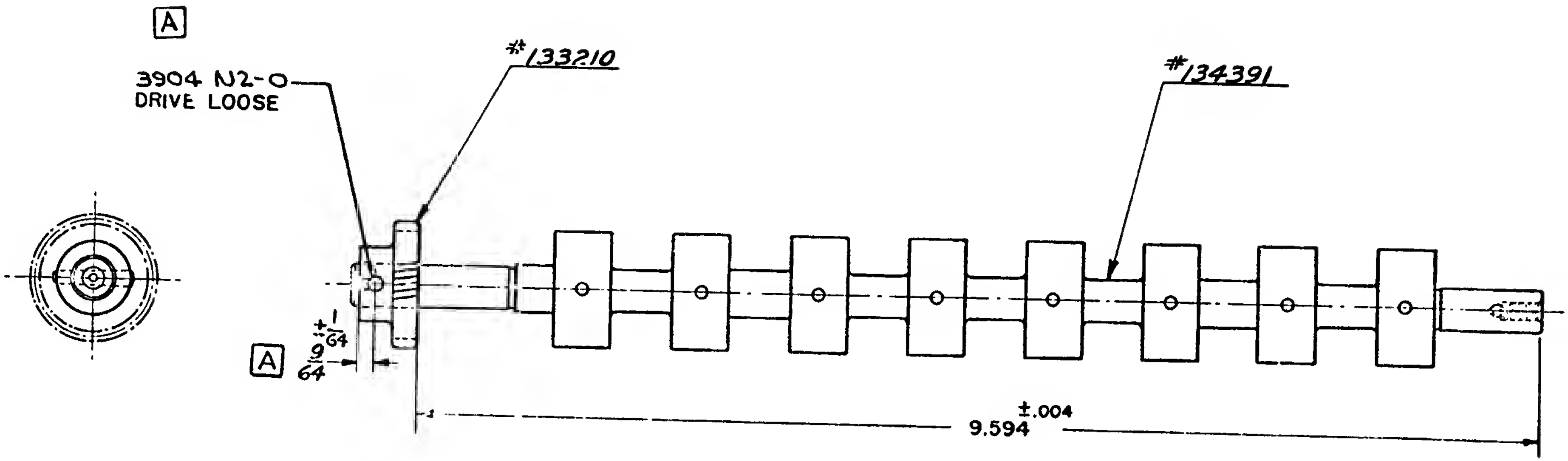
MATERIAL SPECIFICATION	NO.	187173	TOLERANCE UNLESS OTHERWISE NOTED		ALIGNMENT WITHIN	NOTE I	INTERNATIONAL BUSINESS MACHINES CORP.
			DECIMALS	±.001	CONCENTRIC WITHIN TOT. IND. READING	NOTE II	MACH INTERPRETER REPRODUCER
CASE DEPTH			FRACTIONS	±1/64	FLAT WITHIN	NOTE III	515
HARDNESS			ANGLES		PARALLEL WITHIN	NOTE IV	NAME ECCENTRIC SHAFT ASSEMBLY
SURFACE TREATMENT	SPEC NO		CORNERS	OUTSIDE	STRAIGHT WITHIN	NOTE V	DRAW. RM 3-31-53 SCALE FULL SIZE
	TECH RESEARCH APPRO DATE		BROKEN	INSIDE	SQUARE WITHIN IN INCHES	NOTE VI	CHECK AGW 7-9-53
							APPRO. JES 7-20-53

187173

134365

SYM	DATE	CHANGE NO.
	3-7-34	R-295
	4-24-34	778
	6-26-34	999
	1-2-35	2260
	3-6-51	D17882
	9-30-53	SS6
	11-6-53	SS6-A
A2	3-20-59	C800509

STANDARDS CODE
NONE



134365

MUST CONFORM TO
ENG. SPEC. 890350

WT. PER 100 PCS - LBS.

SPECIF.

1	PUNCH
QUAN.	UNIT

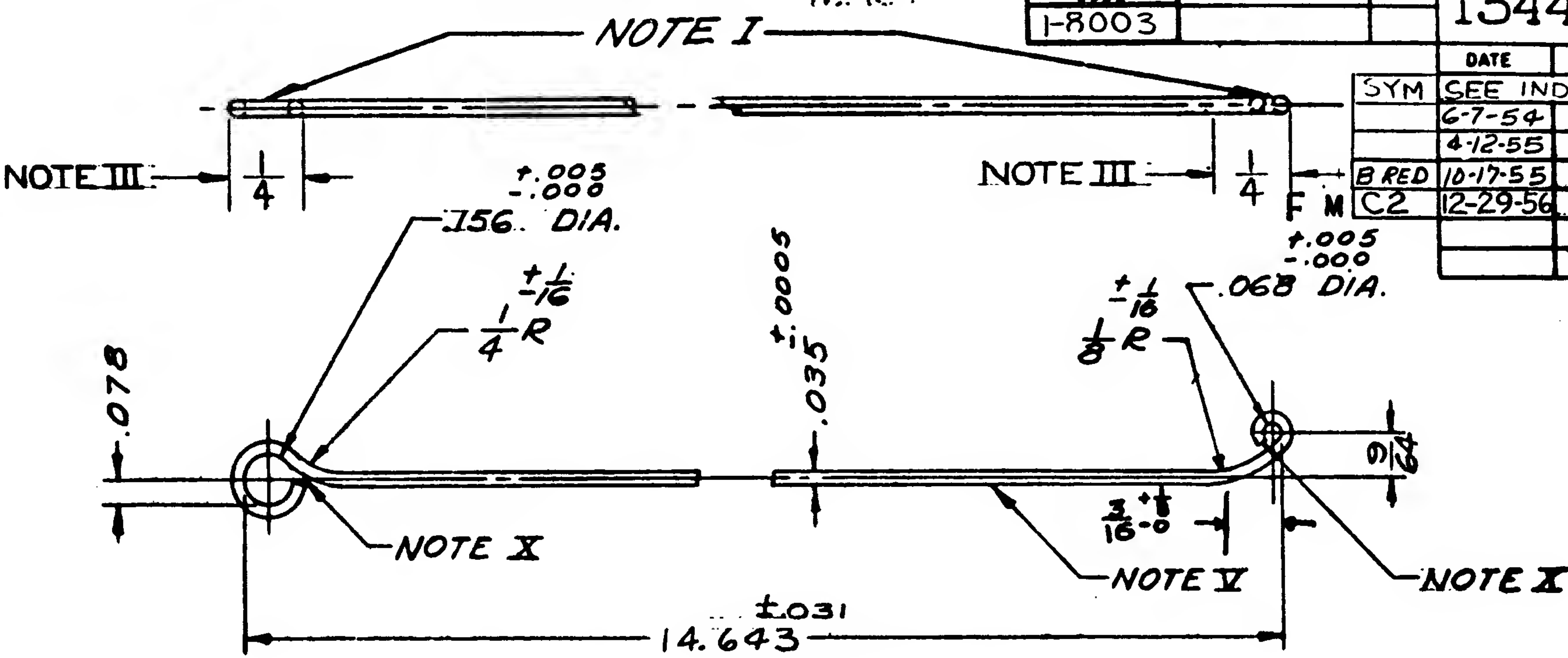
THE TABULATING MACHINE DIV.

MACH.	HIGH SPEED REPRODUCING PUNCH			
NAME	FEED ROLL SHAFT ASSEMBLY			
LOWER CENTER		(PUNCH)		
MODEL		SCALE	FULL SIZE	
DRAWN	E.J.H. 6-21-34	CHECK.	MC	6-26-34
TRAC.	" "	APP. O.	MC	6-26-34

134365

STANDARDS CODE	RELEASED FOR ASSEM	QTY.	134490
1-8003			

SYM	DATE	CHANGE NO.
	SEE INDEX CARD	
	6-7-54	D1939
	4-12-55	D103135
B RED	10-17-55	1362A
C2	12-29-56	1362B



XII SIMILAR TO 134481 THRU 134489

NOTES:

X END MAY BE OPEN 1/32 MAX.

C XI OUT OF ROUNDNESS DUE TO FORMING IS PERMISSIBLE ON EYELETS IF OPENING NOT REDUCED TO LESS THAN MINIMUM I.D SPECIFIED.

STANDARD

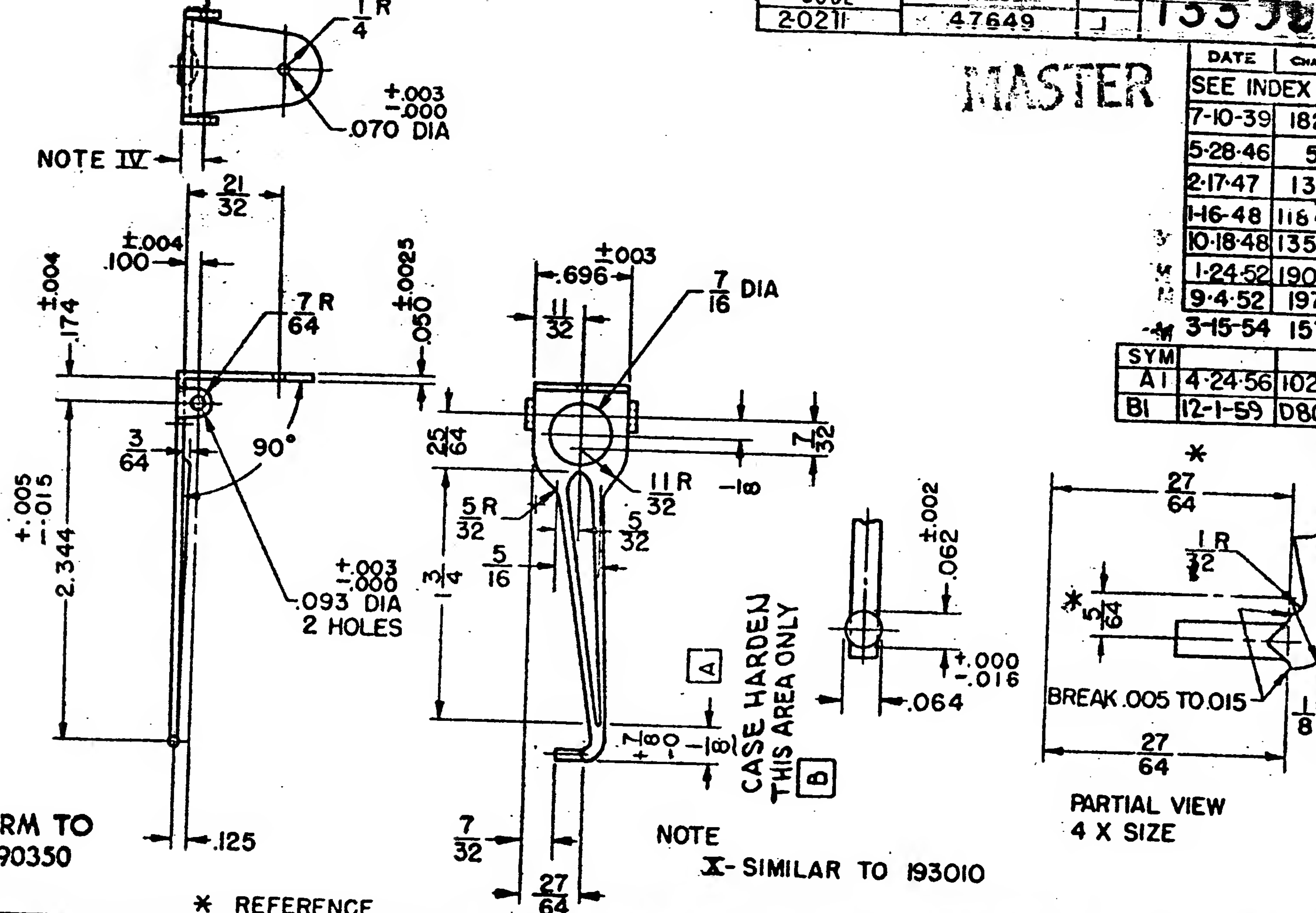
MATERIAL SPECIFICATION NO. 06-640	TOLERANCE UNLESS OTHERWISE NOTED	ALIGNMENT WITHIN .015 NOTE I	INTERNATIONAL BUSINESS MACHINES CORP.
COATED MUSIC WIRE	DECIMALS ± .005	CONCENTRIC WITHIN TOT IND READING NOTE II	MACH REPRODUCING PUNCH MODEL 514
CASE DEPTH	FRACTIONS ± 1/64	FLAT WITHIN .004 C NOTE III	NAME PULLWIRE, MAGNET UNIT
HARDNESS	ANGLES	PARALLEL WITHIN NOTE IV	DRAW KAB 9-20-55 SCALE TWICE SIZE
SURFACE TREATMENT SPEC. NO.	CORNERS OUTSIDE	STRAIGHT WITHIN .015 PER INCH NOTE V	CHECK [illegible] 12-1-55 TRAC VE 10-17-55
134490 TECH APPRO [illegible] RESEARCH DATE 7/26/56	BROKEN INSIDE	SQUARE WITHIN IN INCHES NOTE VI	APPRO AGW 9-28-55 CHECK [illegible] 10-29-55

CODE			
2-0211	47649	J	153[illegible]

MASTER

DATE	CHAN[illegible]
SEE INDEX (	
7-10-39	182[illegible]
5-28-46	55
2-17-47	135
1-16-48	1164
10-18-48	135[illegible]
1-24-52	190[illegible]
9-4-52	197[illegible]
3-15-54	157

SYM		
A1	4-24-56	102[illegible]
B1	12-1-59	D80



PARTIAL VIEW
4 X SIZE

MUST CONFORM TO
ENG. SPEC. 890350

NOTE
X- SIMILAR TO 193010

* REFERENCE

[illegible]AL SPECIFICATION	No. 06-060
STEEL	
[illegible]EPTH 006-.008 SEE DWG.	
[illegible]NESS	
[illegible] CADMIUM	SPEC. No 50
153[illegible]	TECH. RESEARCH APPRO. [illegible]

TOLERANCE UNLESS OTHERWISE NOTED	
DECIMALS ± .005	
FRACTIONS ± ~~1/64~~ 1/64	
ANGLES ± 1°	
CORNERS	OUTSIDE
BROKEN	INSIDE

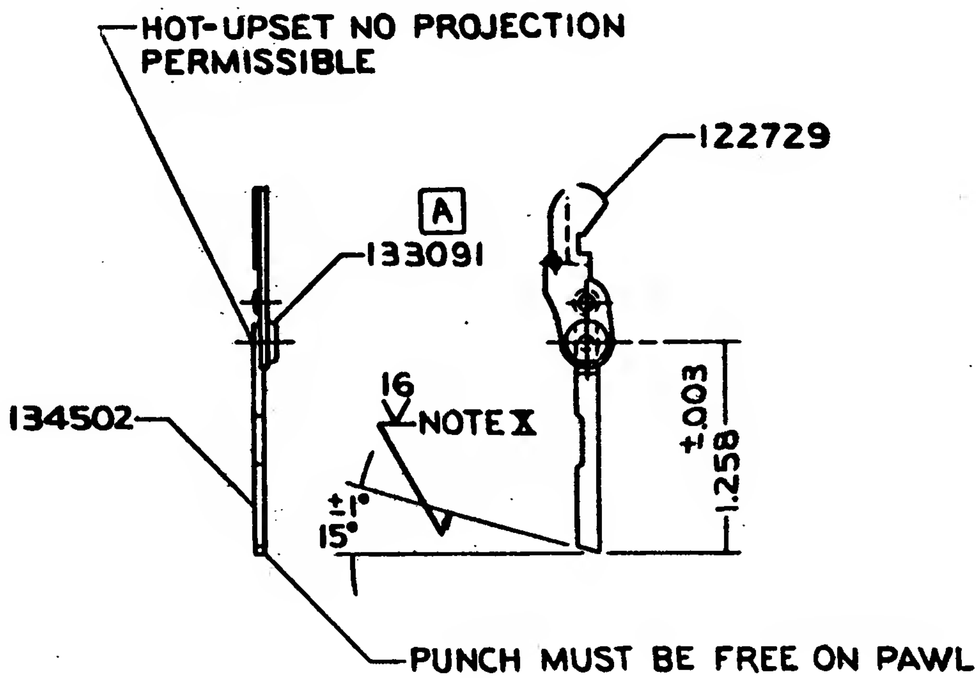
ALIGNMENT WITHIN	~~TOT. IND. READING~~	NOTE I
CONCENTRIC WITHIN	TOT. IND. READING	NOTE II
FLAT WITHIN .020 IN 2 1/2	~~TOT. IND. READING~~	NOTE III
PARALLEL WITHIN .004	~~TOT. IND. READING~~	NOTE IV
STRAIG[illegible]T WITHIN	~~TOT. IND. READING~~	NOTE V
SQUARE WITHIN IN	INCHES	NOTE VI

INTERNATIONAL BUSINESS MACHINES CO[illegible]			
MACH.	HIGH SPEED REPRODUCIN[illegible]		
	PUNCH	MODEL	512
NAME	ARMATURE		
DRAW.	E.H.M. 6-22-34	SCALE	FULL SI[illegible]
CHECK	B.D.S. 6-23-3[illegible]	[illegible]AC.	C.B.E. 5-[illegible]
APPRO.	W.G.L. 6-26-34	CHECK	E.S. 5[illegible]

STANDARDS CODE	RELEASED FOR ASM	QTY
NONE	208598	1

SYM	DATE	CHANGE NO
	2-4-58	800116
A1	4-23-58	D800168

DEVELOPMENT NO	Q/M
600970	



NOTE

X CUTTING EDGES OF THE PUNCH TO BE LEFT SHARP

MATERIAL SPECIFICATION	NO	
CASE DEPTH		
HARDNESS		
SURFACE TREATMENT		SPEC NO
600970	TECH SERVICES APPRO	DATE

TOLERANCE UNLESS OTHERWISE NOTED	
DECIMALS	
FRACTIONS	
ANGLES	
CORNERS AND/OR EDGES BROKEN	OUTSIDE
	INSIDE

ALIGNMENT WITHIN	NOTE I
CONC TO WITHIN	TIR NOTE II
FLAT WITHIN	NOTE III
PARALLEL TO WITHIN	NOTE IV
STRAIGHT WITHIN	NOTE V
SQUARE TO WITHIN	NOTE VI

INTERNATIONAL BUSINESS MACHINES CORP

NAME	INTERPOSER PAWL AND PUNCH ASSEMBLY-1ST COL				
DESIGN	RJK	1-9-58	MODEL	514	
DETAIL	RJK	1-9-58	SCALE	1/1	
CHECK	VWR	1-21-58	DRAW	PEC	2-24-58
APPRO			CHECK	[illegible]	3-24-58

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INTERNATIONAL BUSINESS MACHINES CORPORATION (C)

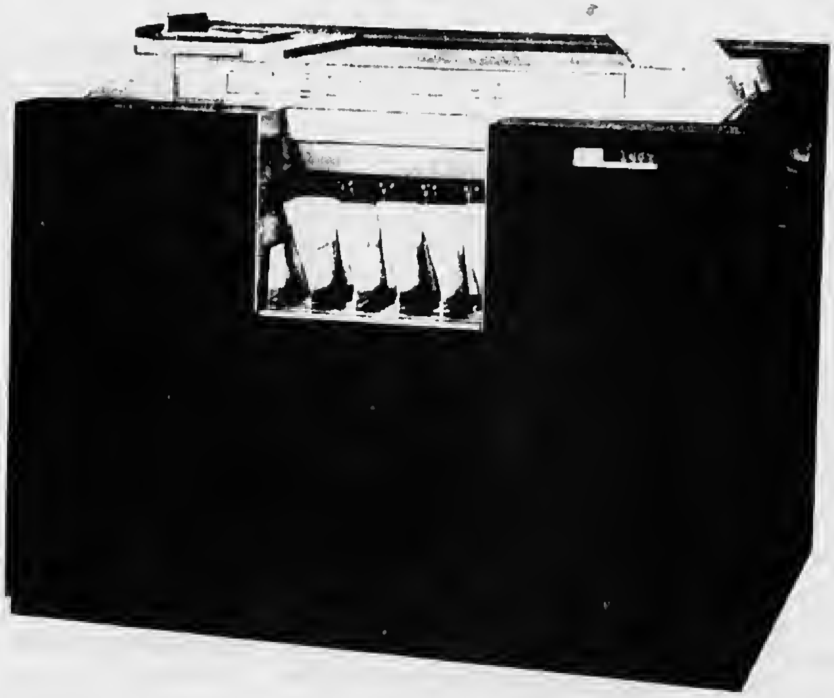
Description of the IBM 1402 Card Punch

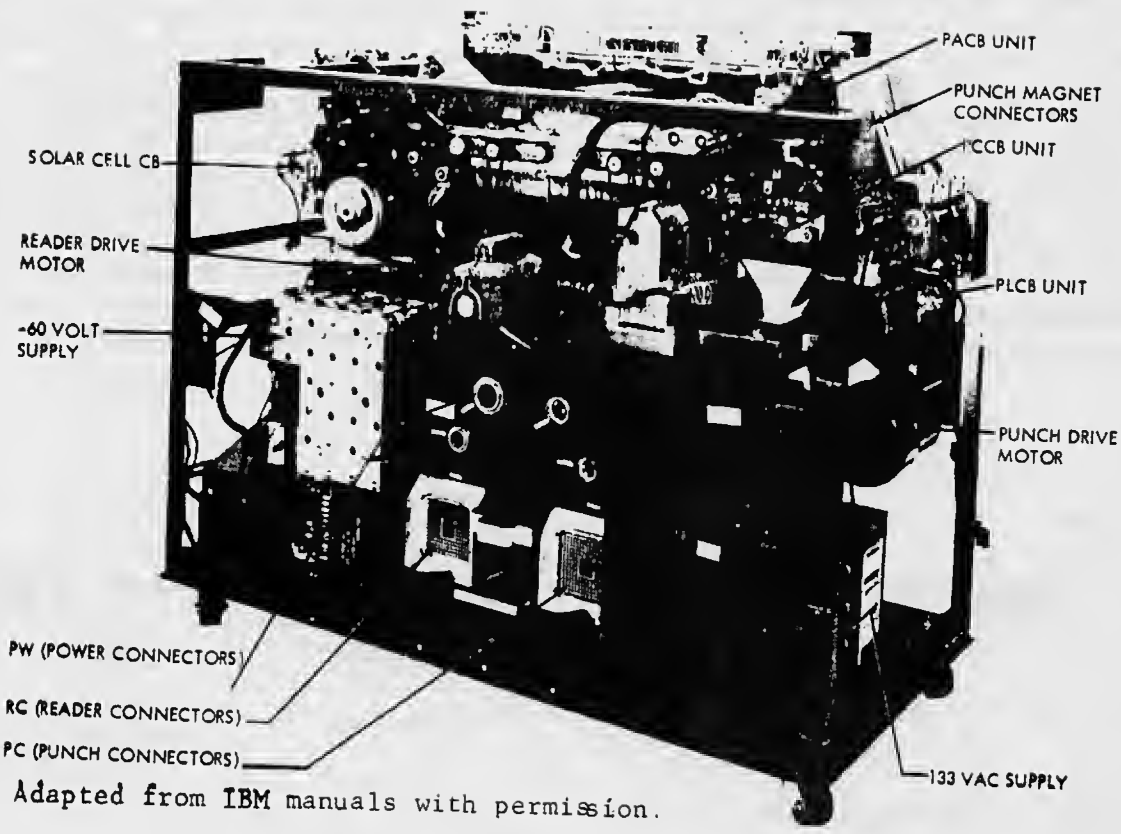
An Engineering Case Study

While International Business Machines Corporation has cooperated with Stanford in encouraging the development of this course material and in supplying basic information and documentation, the company has not reviewed the course manuals and has had no part in their preparation and therefore does not necessarily concur with any opinions expressed or attest to factual accuracy. IBM wishes explicitly to avoid such intervention in order to allow complete editorial freedom to the University.

Prepared in the Design Division of the Mechanical Engineering Department, Stanford University, by Bernard Roth and Karl H. Vesper, as a basis for student projects with financial support from the National Science Foundation.

Description of the
1402 Punch





Source: Adapted from IBM manuals with permission.

IBM 1402 Card Read-Punch

The IBM 1402 Card Read-Punch provides a data processing system with punched-card input and output. The read feed is equipped with a file feed which has a capacity of 3000 cards. The read feed can process cards at a speed of 800 cards per minute. Punching speed is 250 cards per minute. Five radial-type stackers are used to accomplish stacking of the cards. The card transport system is driven by timing belts wherever possible to reduce machine noise and maintenance.

Functional Principles

The 1402 Card Read-Punch can read cards at a maximum speed of 800 cards per minute. Actual card speed is governed by the program routine. The read feed is equipped with a 3000 card-capacity file feed. The cards are fed through the read feed, 9-edge first, face down. The card feed path is illustrated in the feed schematic diagram (Figure 1). As the card passes the read-check brushes, 80 columns of the card are read. It is then moved past the read brushes where again 80 columns of the card are read. Next, it is transported past the stacker selection station and is directed to the appropriate stacker under control of programming. Three stackers are available to receive cards from the read feed. The NR (Normal Read) stacker is used unless the cards are program-directed to stacker 1 or stacker 8/2.

The 1402 Card Read-Punch will punch cards and check card punching at a maximum speed of 250 cards per minute. Cards are placed in the 1200 card-capacity hopper, 12-edge first, face down. Card feeding is illustrated in the feed schematic diagram (Figure 1). Before the card is punched, it is aligned at the aligner station to insure correct punching registration.

Punching is done by a high-speed punch unit. After the card is punched, it is read at the 80-column punch-check brushes. It is then moved past the stacker selection station and is directed to the appropriate stacker under program control. Three stackers are available to receive cards from the punch feed. The NP (Normal Punch) stacker is used unless the cards are program-directed to stacker 4 or stacker 8/2.

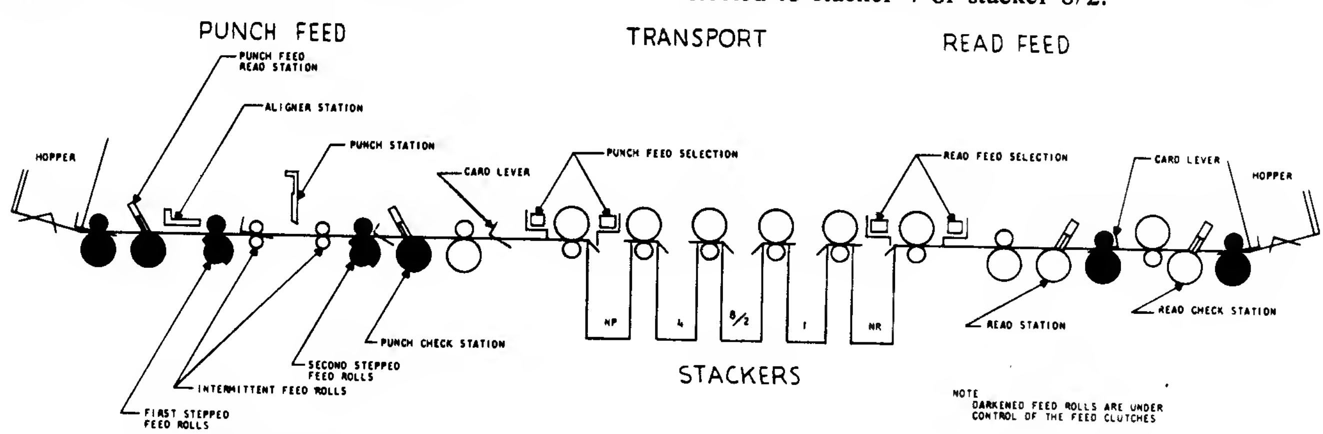


Figure 1· 1402 Feed Schematic

Card Selection Mechanism (Figure 2)

The read feed and the punch feed each can have cards go into only three of the five stackers on the IBM 1402. The stacker into which the card enters is determined by the selection mechanism at each end of the transport section. This mechanism consists of two chute blades and two control magnets for each of the read and the punch feeds. With the select magnets de-energized, the cards enter the stacker nearest the feed: stacker NR for the read and stacker NP for the punch. If the magnet that depresses the lower of the two chute blades is energized, the cards go into stacker one or four. If the magnet that depresses both chute blades is energized, the cards from either feed can go into stacker 8/2.

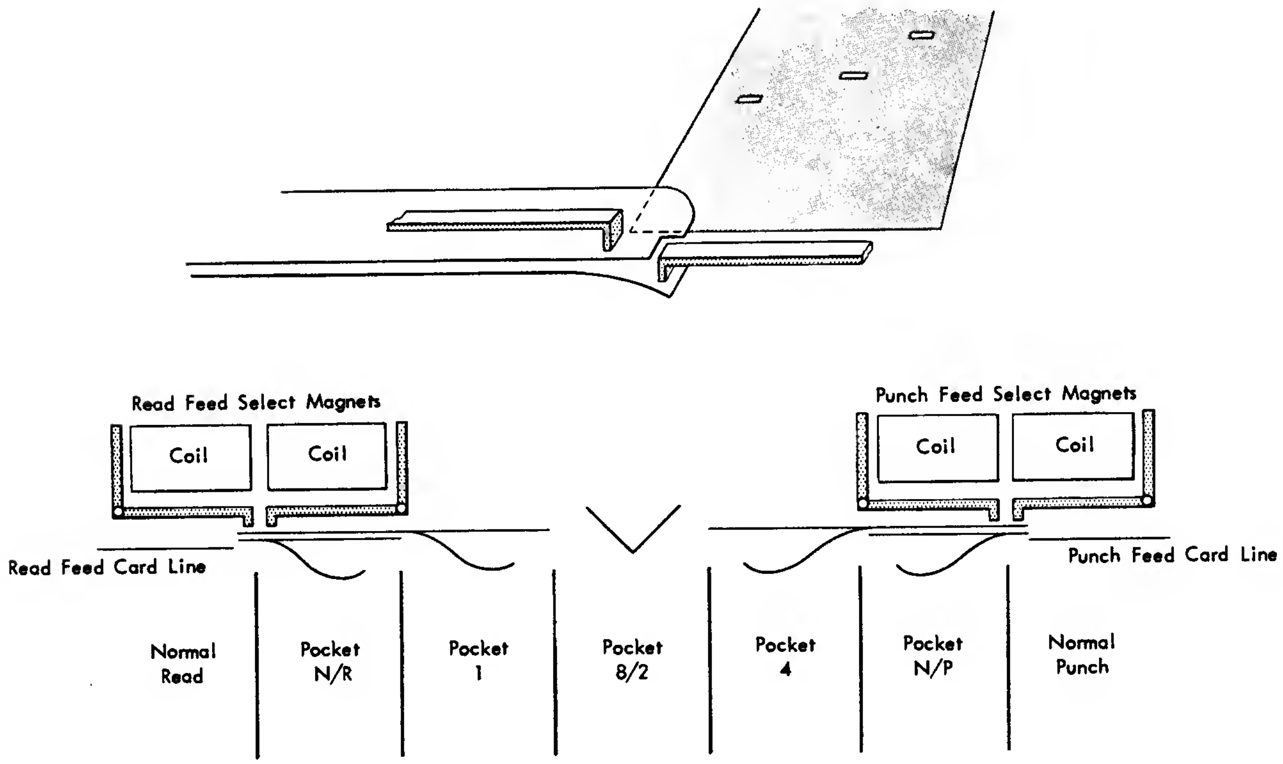


Figure 2 Card Selection Schematic

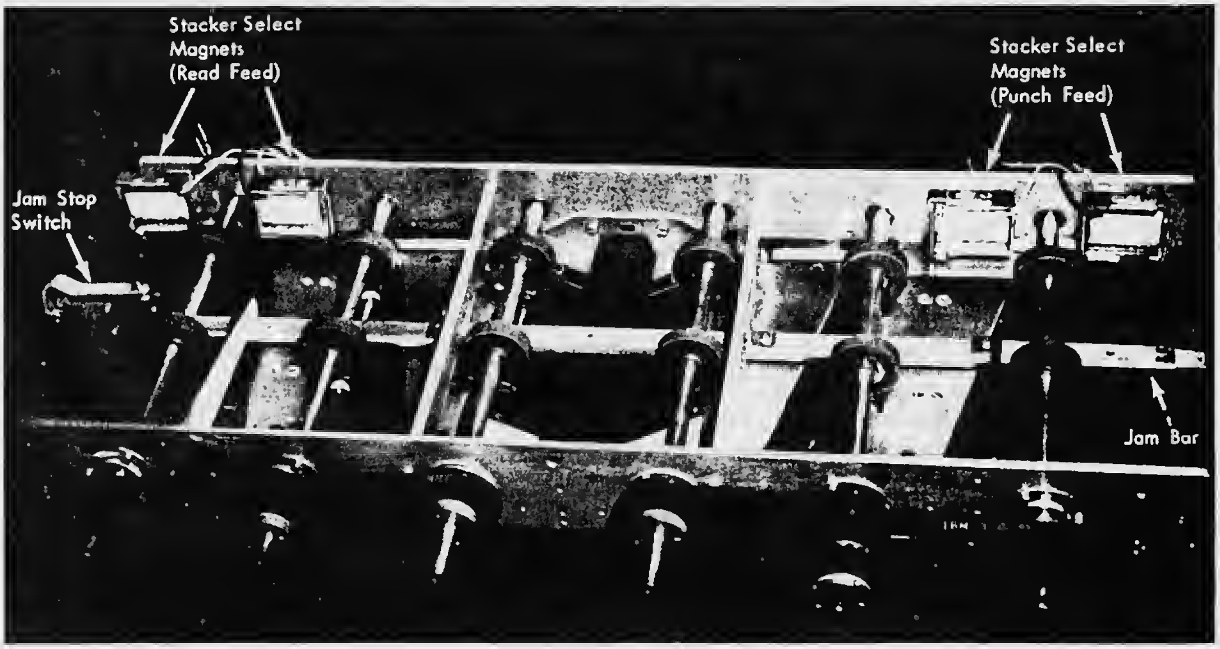


Figure 3 Transport Mechanism

Transport Mechanism (Figure 3)

The transport mechanism consists of six continuously running feed rolls that move the cards from the feeds to the stackers selected by the chute blades. Three of the feed rolls are under the control of the read feed, and three are under control of the punch feed. A jam bar is installed over the length of the transport mechanism. The bar consists of a spring steel strip located just above the normal card line. Any card that is bent enough to flex the metal strip causes a switch to operate. The switch causes the machine to stop and turns on the STOP light. A card jam in the feed portion of the machine is detected by other circuits.

Stackers (Figures 4 and 5)

The stackers used on the 1402 are the radial type. The stacker receives the card from the transport mechanism with the card horizontal. The distance from the top of the guide assembly to the lip of the pivot and lever assembly is less than the length of the card. As a result, the front of the card is held by the card restraining lever, and the rear of the card falls, guided by the guide assembly. The radius of the guide assembly is such that as the rear of card approaches the bottom, the front falls from the card restraining lever that has been supporting it.

Figure 4 Stacker

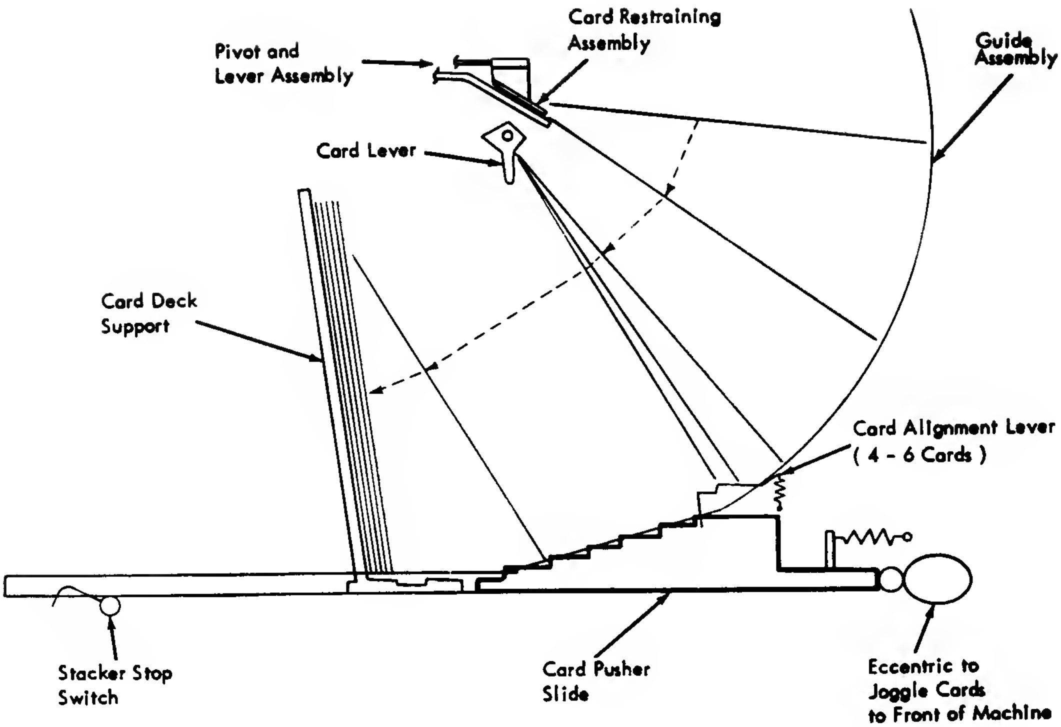


Figure 5 Stacker Schematic

The card stops with the back edge on the card alignment lever and the front edge on the card deck support or card previously stacked. Spring tension supports the card alignment lever until 4-6 cards accumulate. Their weight overcomes the spring tension supporting the card alignment lever, and lowers the group of cards into the card pusher slide. The pusher slide oscillating front to back works the bottom of the cards to the front so they are standing against the card deck support. This can continue until the card deck support moves out enough to operate the stacker stop microswitch operating arm, which stops the machine. The card joggler mechanism is driven from either or both the punch and the read feeds.

The card levers on the pivot and lever assembly keep the cards from going back into the stacker where they might jam the machine.

Punch Feed

Drive Mechanism

A ⅓ hp motor is used to drive the input idler pulley. Through gears and timing belts the following are kept continuously running:

1. Timer index
2. Clutch ratchet
3. Geneva assembly
4. Intermittent feed rolls
5. Punch drive shaft
6. PACB's
7. PCCB's
8. Three transport feed rolls
9. Stacker jogglers

When the punch clutch engages, power is transmitted to the following:

1. Picker knife camshaft
2. Feed knives
3. First feed rolls
4. First stepped roll assembly
5. Card aligners
6. Second stepped roll assembly
7. Punch check brush contact roll
8. First feed roll after the punch check brushes
9. PLCB's

When the punch clutch latches, the intermittent feed rolls are cammed open so that they cannot feed the card even though they continue to turn.

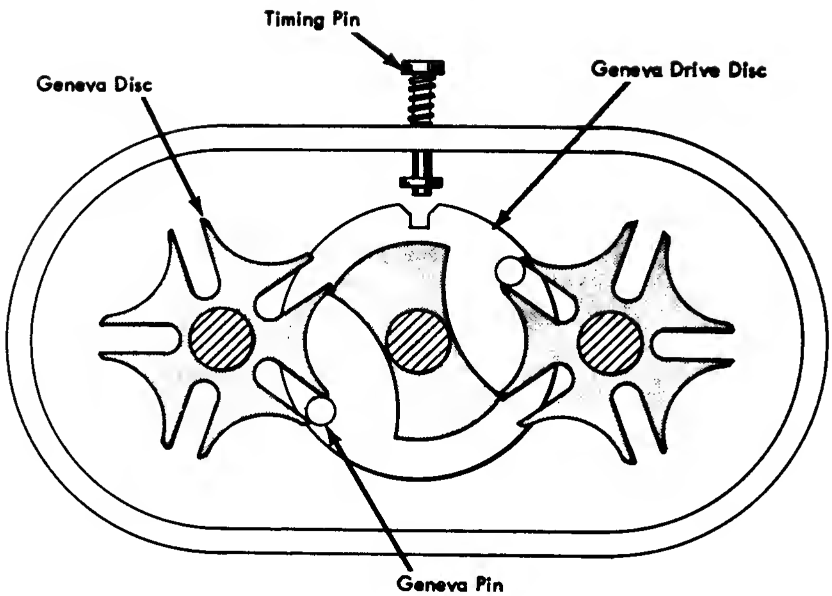


Figure 6 Geneva Mechanism

Geneva Mechanism (Figure 6)

The geneva drive housing contains two geneva discs and the geneva drive disc. If trouble is experienced in this unit, replace it with a new geneva drive housing.

The geneva operates on the same principle as the genevas in other high-speed punches. When the geneva pins ride into the deep cuts in the geneva discs, the feed rolls are driven by the gears attached to the geneva discs. As the geneva pins leave the deep cuts in the geneva discs, the cam surface on the geneva drive disc contacts the shallow cuts on the geneva discs. When the cam surface is in the shallow cuts of the geneva discs, the intermittent feed rolls are held stationary. The geneva action is repeated every cycle point causing an intermittent movement of the card through the punching station.

Punch Feed Clutch

The punch clutch used on this machine is a 4-tooth ratchet type. The clutch pawl engaging time is 315°.

Picker Knives (Figure 7)

The feed knives travel in an arc instead of in a flat plane parallel to the card line. Each picker knife block is mounted on an arm which is attached to the picker knife shaft. The block assemblies are fixed on the arms and are not adjustable to the arms. Two carballoy pieces are inserted in the knife blocks so that the knives will resist wear. The inserts are ground to specifications for knife projection, and replacement of the picker knife block is required when it becomes worn.

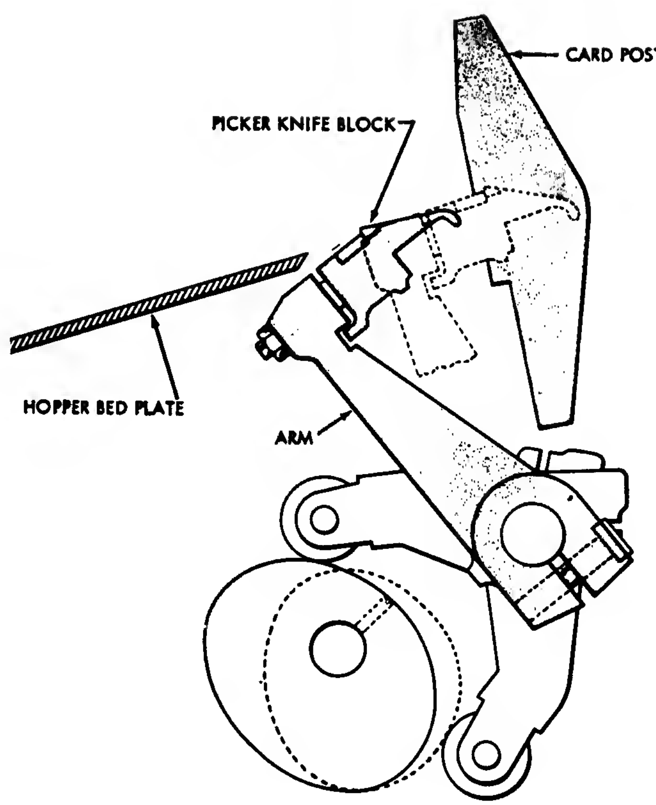


Figure 7 Picker Knives

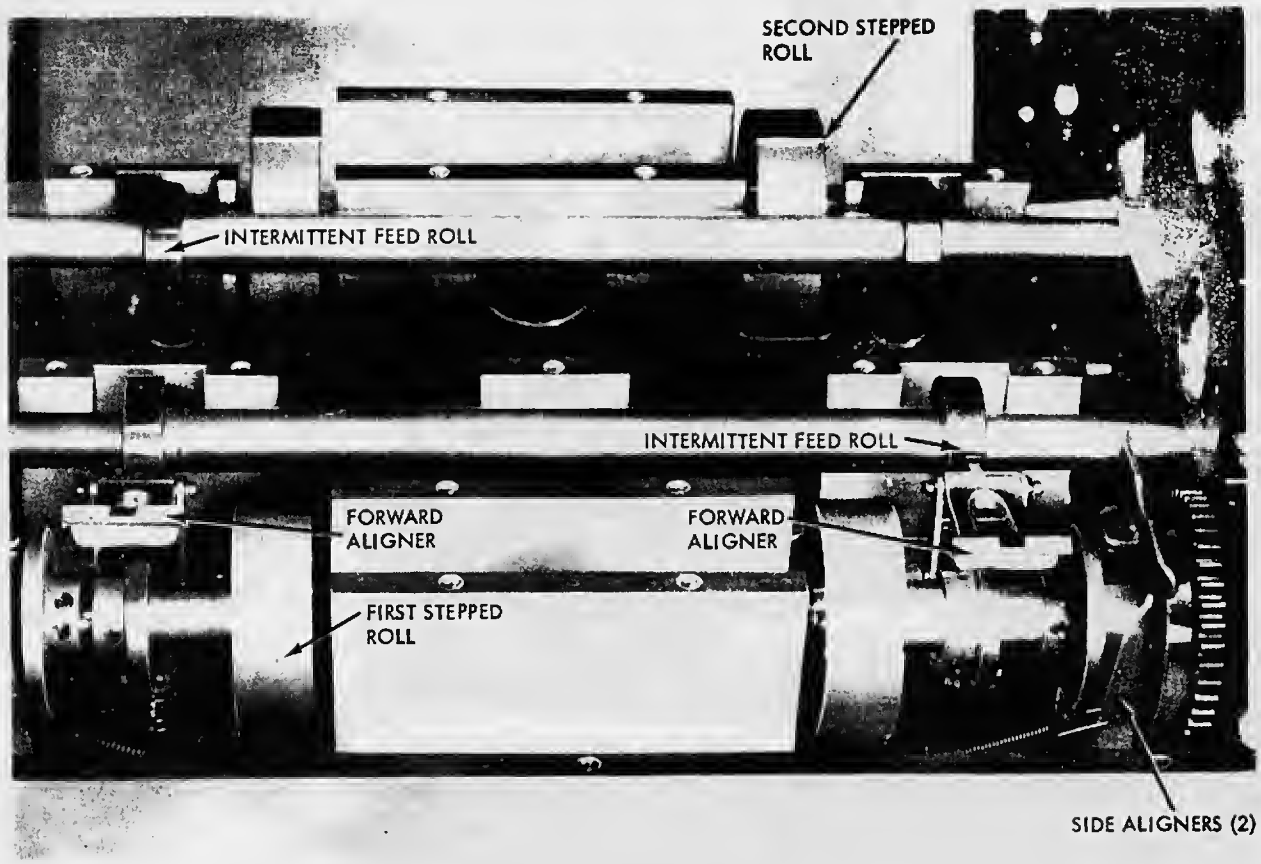


Figure 8 Aligner Station, Stepped & Intermittent Feed Rolls

Punch Check-Brush Station

One set of 80-column reading brushes is used after the punch station for checking card punching. The brush assembly is inserted and removed from the top of the machine. Upon release of the locking pins, the brushes retract into the brush separator so that the brushes will be protected when they are out of the machine.

The punch check brush contact roll is connected to its drive shaft by a helical spring drive. The spring is tight on the shaft when the contact roll is driven in the proper direction, but, if the drive is reversed, the spring will allow the contact roll to remain stationary, preventing damage to the brushes.

Aligner Station and Intermittent Feed Rolls (Figure 8)

As the card passes the first upper-card guide, it is picked up by the first stepped-roll assembly. The lower roll of the assembly is called a stepped roll, because it has a portion of its circumference cut away. When the high dwell of the stepped roll is opposite the upper roll, the card is fed through the rolls into the first intermittent rolls which are cammed open at this time. When the low dwell of the stepped roll is opposite the upper roll, collars on the end of the stepped roll assembly shafts prevent the stepped roll from contacting the card.

During the time that the card is free from the stepped feed roll and intermittent feed roll, it is aligned to insure correct punching registration. The forward aligners contact the trailing edge of the card and move the card up to the centerline of the punches. At the same time, the card is aligned toward the column-80 end by the side aligners. Card pressure fingers are used at the aligner station to hold the card, so it does not snap or buckle.

After aligning is completed, the first intermittent feed rolls close, and they start feeding the card through the punching station. The second intermittent feed rolls are cammed open as the card is fed into them. They then close, just before the card leaves the first intermittent feed rolls. After the second intermittent feed rolls close, the first intermittent feed rolls are cammed open. When the first intermittent feed rolls open, the feeding of the card through the punching station is under control of the second intermittent feed rolls. The opening and closing of the intermittent feed rolls prevent buckling or snapping of the card at the punch station.

While punching is being completed, the card is fed into the second stepped-roll assembly which does not

Figure 9 Roll-Opening Device

contact the card at this time. The second stepped-roll assembly is like the first stepped-roll assembly ahead of the aligner station. The second stepped roll contacts the card after the second intermittent feed roll releases the card and feeds it past the second brushes into the sixth feed roll. The sixth feed roll will take over control of card feeding when the second stepped roll comes to the low dwell in its circumference. After card reading, the card is under control of three constant speed feed rolls. Card selection is performed as the card passes these rolls. Refer to *Read Feed* for Card Selection and Stacker Operation.

Roll-Opening Device (Figure 9)

The two stepped rolls, the two lower intermittent rolls, and the die assembly are mounted on one assembly called the roll-opening device. This assembly may be lowered to facilitate removal of card jams. The handle on the left side of the machine is pulled out and turned clockwise to lower the device and counterclockwise to raise the device. The locating blocks for the die are also in this frame, making die insertion and removal easier.

An electrical contact interlocks the roll-opening device so that the device must be in its UP position before the machine will operate.

Punch Unit (Figure 10)

The entire punch unit can be easily removed from the machine for servicing. It can be separated into two main assemblies as follows:

1. The drive unit (Figure 11)
2. The magnet unit (Figure 12)

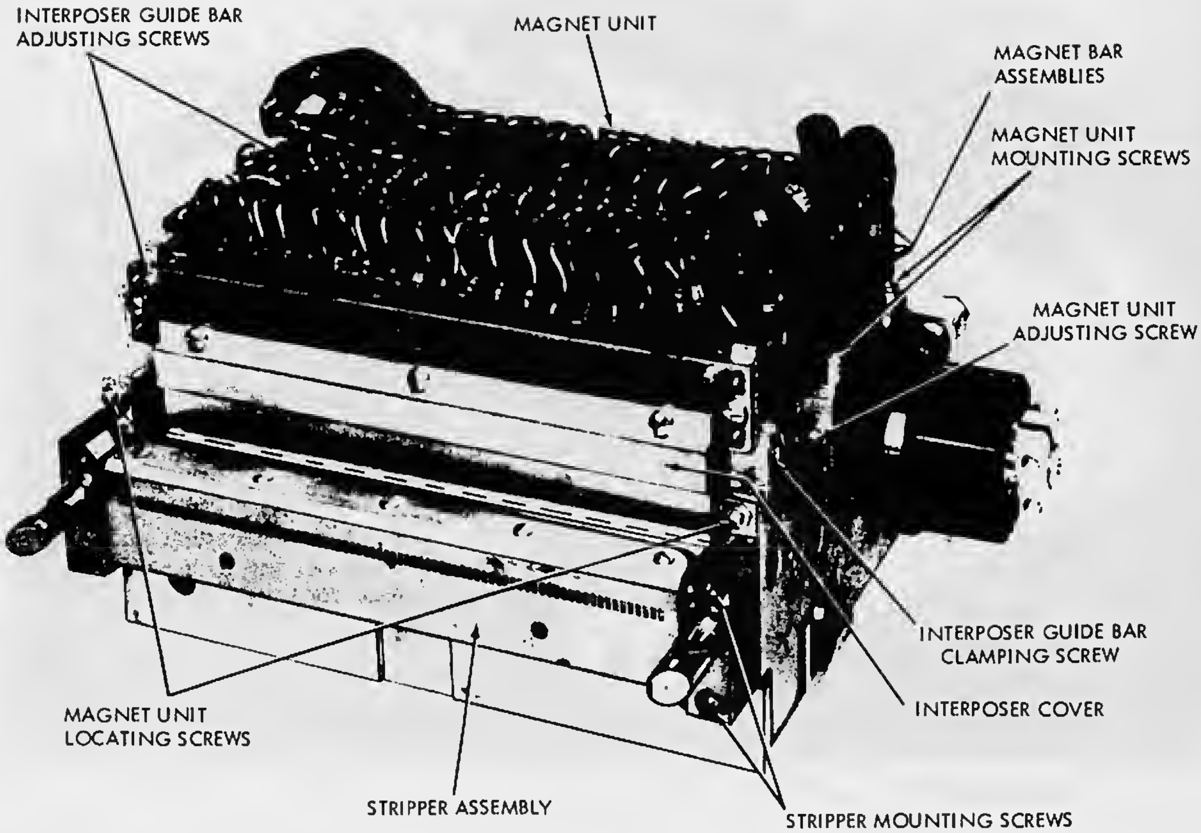


Figure 10. Punch Unit

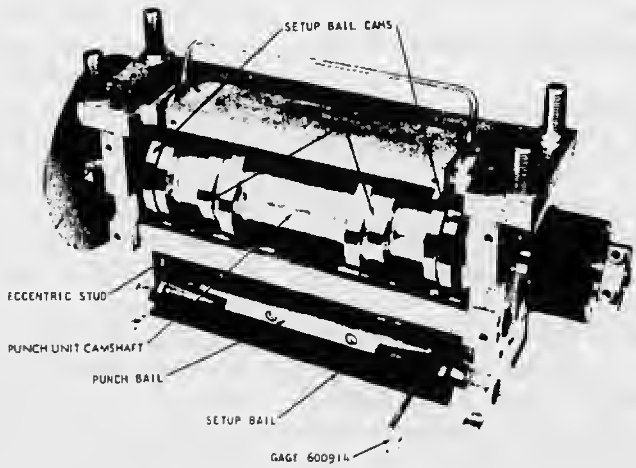


Figure -11. Drive Unit

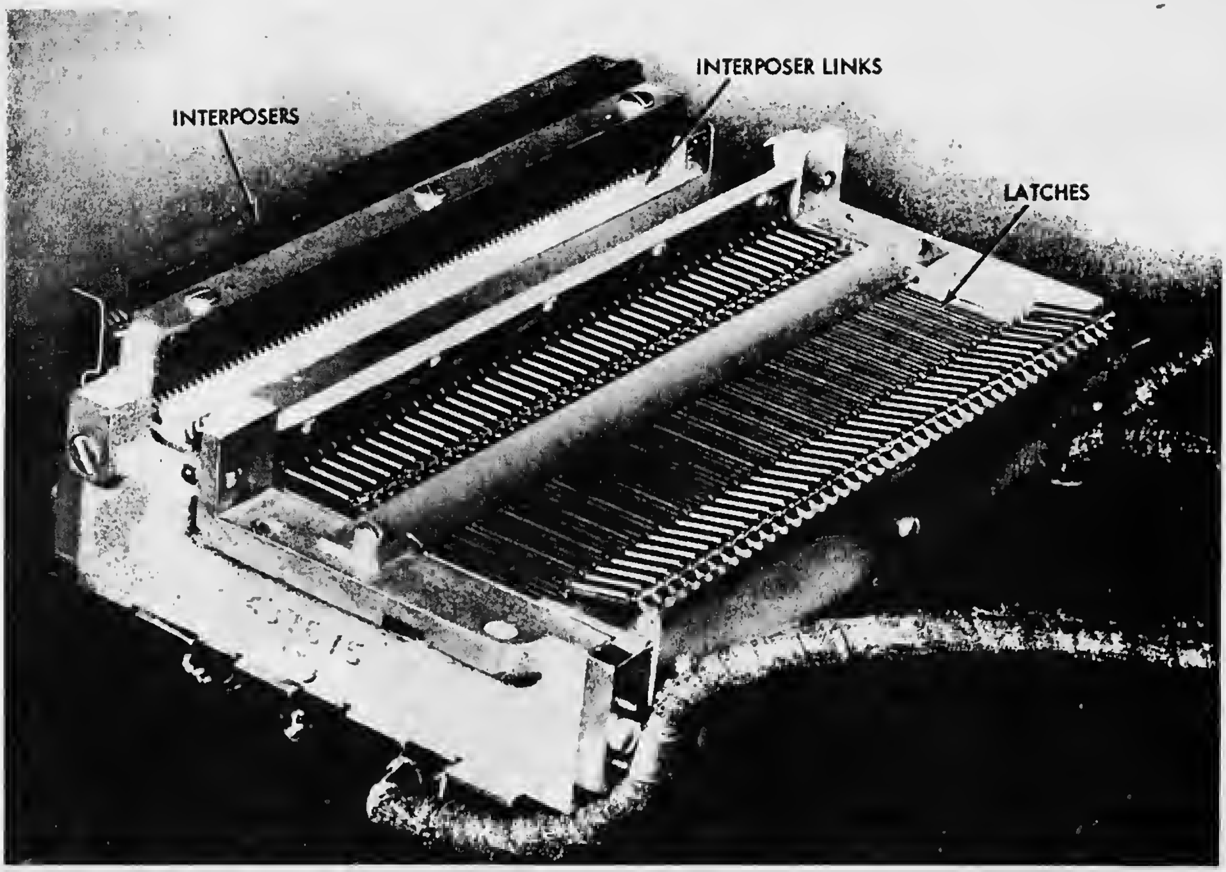


Figure 12 Punch Magnet Unit

The drive unit can be further divided into the following units:

1. Punch drive unit
2. Punch bail and setup bail cam follower assembly
3. Die and stripper assembly

The punch drive unit consists of a cam shaft and four sets of complementary cams.

The punch bail and setup bail cam follower assembly consist of

1. A punch bail and two sets of cam follower arms
2. An interposer setup bail and two sets of cam follower arms

The punch magnet unit consists of eighty magnets, latches, interposer links, and interposers. The magnets are connected through miniature multi-terminal connectors to the machine circuits.

The cam shaft in the punch drive unit operates continuously when the motor is operating. The three-lobed cams operate the interposer setup bail and punch bail three times on each revolution of the punch camshaft. The punch camshaft makes 1333⅓ revolutions per minute.

The interposer setup bail is a U-shaped channel. A projection on each of the 80 interposer links ride in the channel (Figure 13). As the interposer setup bail moves down, all the interposer links move down, carrying with them the 80 latches. This pulls each armature against its yoke. If punching is to take place, the magnet is energized at this time. Because the armature did not have to be attracted electrically, very low current is required to keep the armature sealed against its yoke. For this reason the unit is sometimes referred to as a "no-work" type punch unit.

When the interposer setup bail moves up, the magnet just energized keeps its latch in the DOWN position. Because the latch is stationary, the upward movement of the interposer setup bail causes the interposer link to pivot, extending the interposer between the punch bail and the punch.

The movement of the punch camshaft then causes the punch bail to move down. Only those columns are punched that have the interposers between the punch bail and the punch. When the punch bail pushes the interposer down, the interposer is clamped between the punch and the punch bail. With this arrangement, the magnet can be de-energized while the punch is going down rather than waiting until the completion of the punching operation.

As the punch bail returns the interposer is free to be restored by spring tension. On the return stroke of the punch bail, the punch is positively restored by the projection on the punch bail.

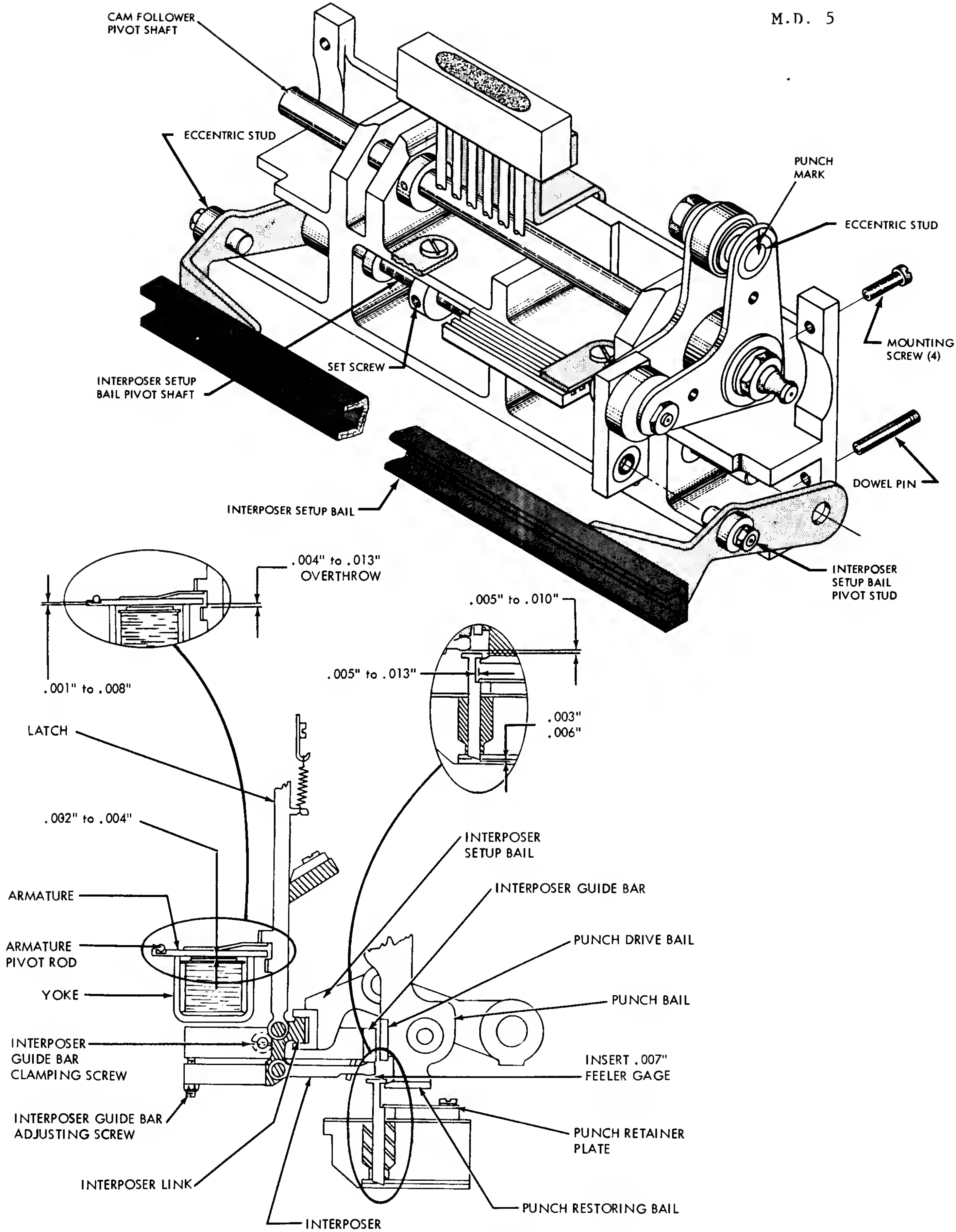
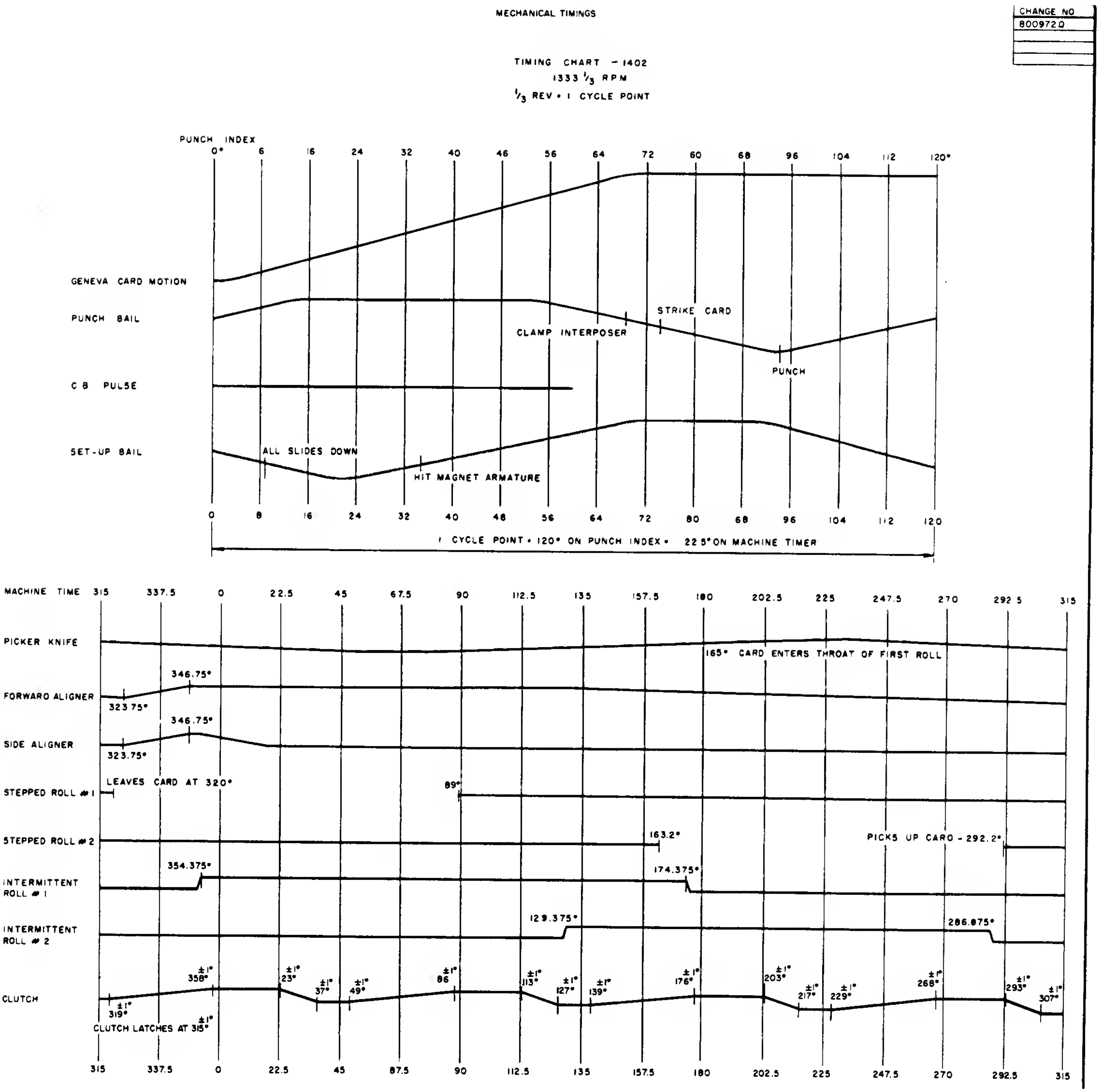


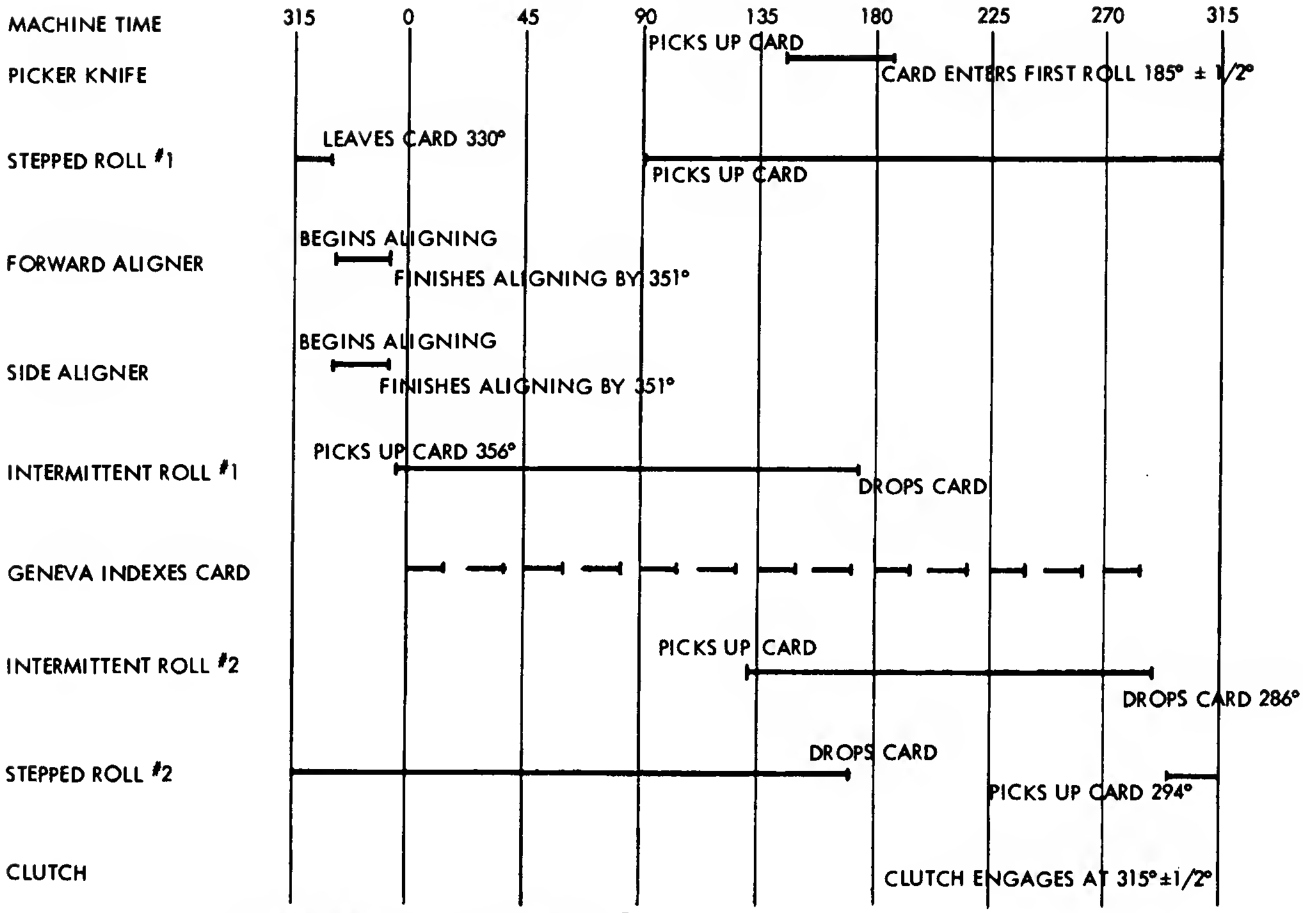
Figure 13. **Punch Unit**

Timing

Following are three timing charts of the 1402 and a schematic of the timing belts. Punch indices on the timing charts are in degrees of rotation of the punch clutch.



PUNCH TRANSPORT TIMING

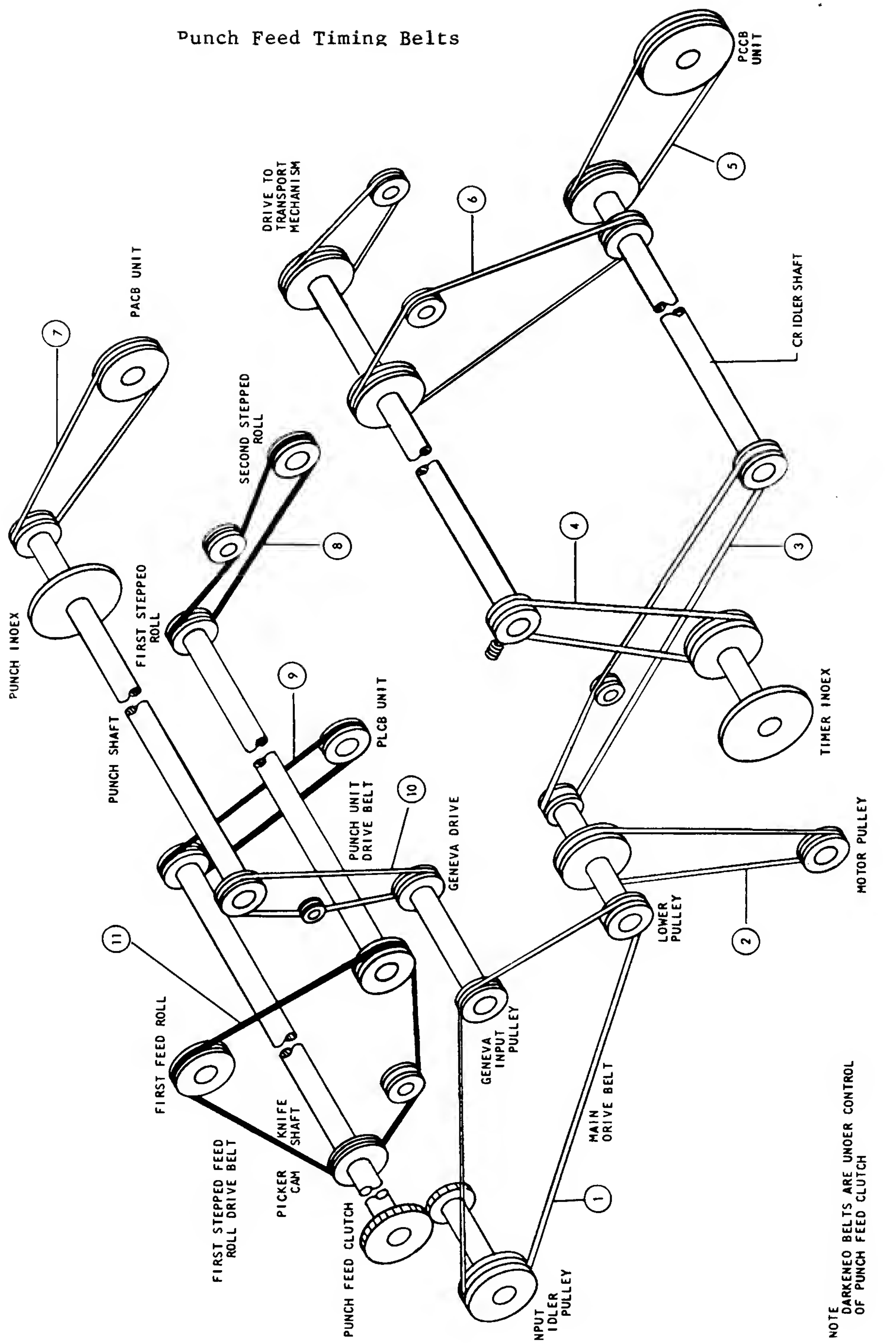


CRITICAL MACHINE TIMINGS ARE NOTED

Timing Belts (See Schematic Following)

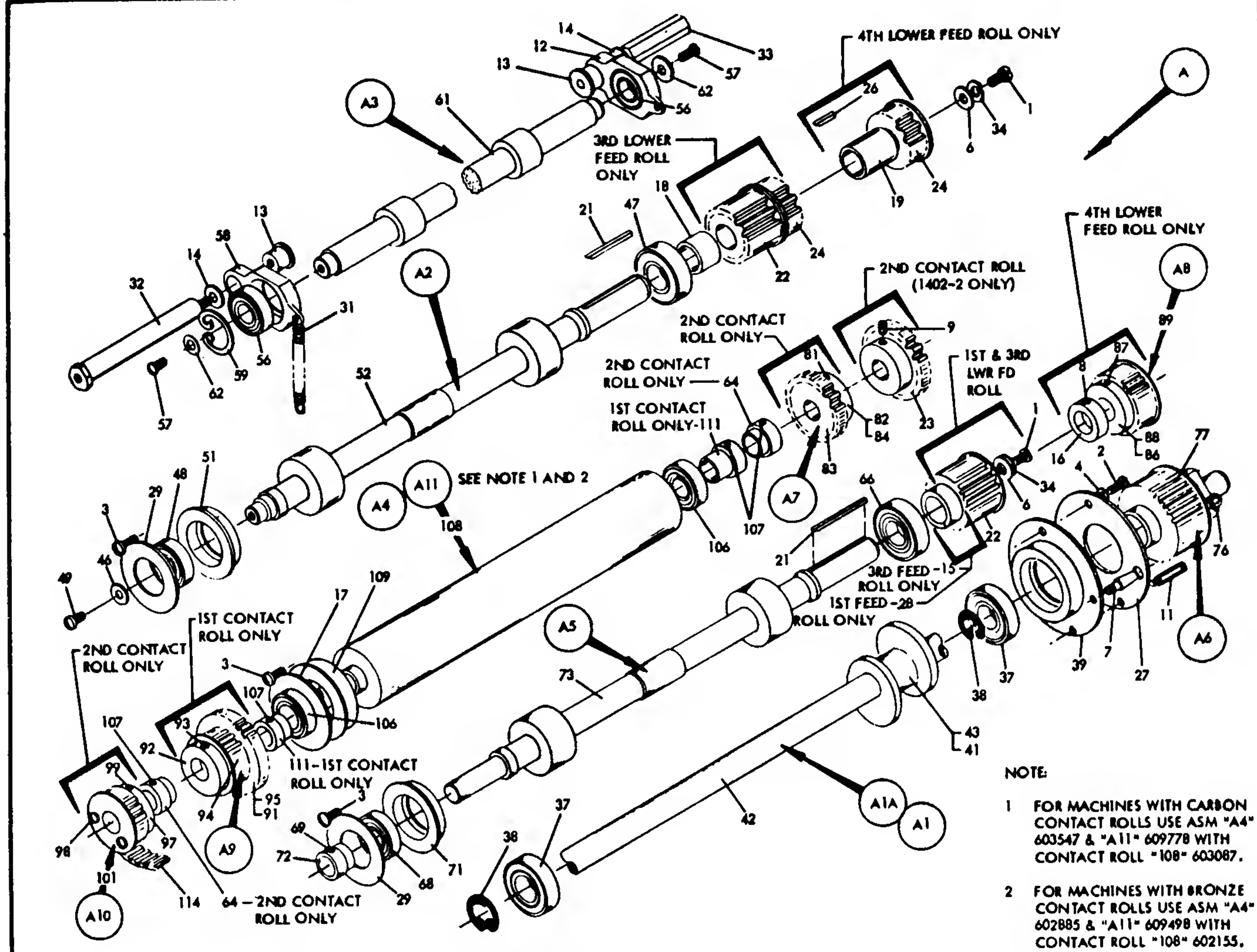
Belt Name and Reference Number	Belts or Units To Be Removed	Units to be Retimed After Belt Replacement
(1) Main Drive Belt		Punch Clutch, Geneva
(2) Drive Motor Belt	CR Idler Belt (3)	Timer Index, PCCB Unit
(3) CR Idler Belt	* Timer Index	Timer Index, PCCB Unit
(4) Timer Index Belt	* Timer Index	Timer Index
(5) PCCB Belt		PCCB Unit
(6) Idler Belt	PCCB Belt (5) Belt to Transport Assembly	Timer Index, PCCB Unit
(7) PACB Belt	PACB Unit	PACB Unit
(8) Second Stepped Feed Roll Belt		Second Stepped Feed Roll
(9) PLCB Belt		PLCB Unit
(10) Punch Unit Drive Belt		Punch Unit
(11) First Stepped Feed Roll Drive Belt	Main Drive Belt (1) *Punch Input Idler Pulley *Punch Drive Gear Spring (Cam Follower)	Punch Clutch, Geneva First Stepped Feed Roll

Punch Feed Timing Belts



NOTE
DARKENEO BELTS ARE UNOER CONTROL OF PUNCH FEED CLUTCH

LOWER FEED ROLLS ASMS.



NOTE:

1 FOR MACHINES WITH CARBON CONTACT ROLLS USE ASM "A4" 603547 & "A11" 609778 WITH CONTACT ROLL "108" 603087.

2 FOR MACHINES WITH BRONZE CONTACT ROLLS USE ASM "A4" 602885 & "A11" 609498 WITH CONTACT ROLL "108" 602155.

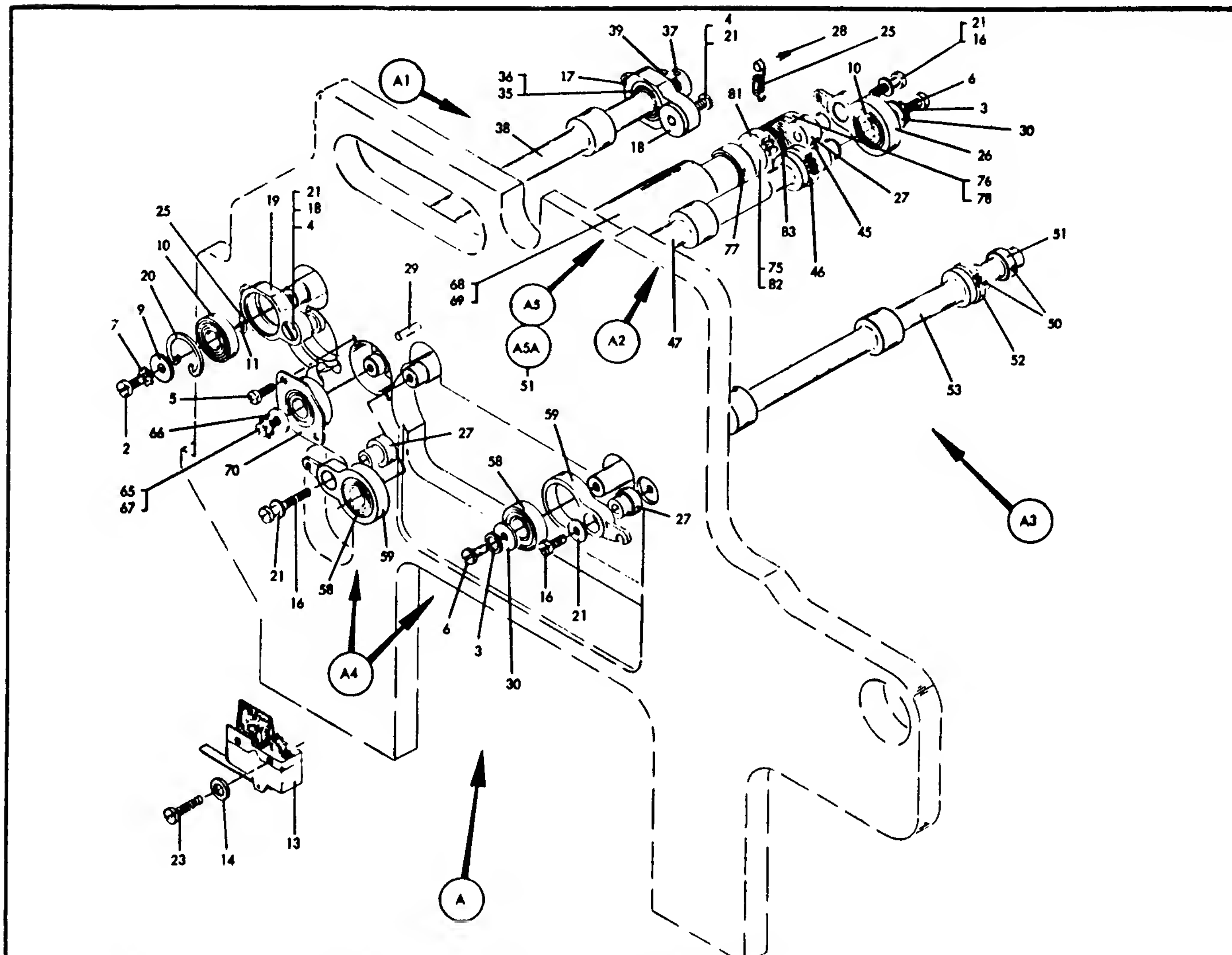
FOR REMAINDER OF THIS ASM SEE FIGS 5 THRU 10

*A	609110	READER FEED ASM 1402
*A	614006	READER FEED ASM 1402-2
1	845	SCREW
2	25627	SCREW-BRG RET MTG
3	38235	SCREW-BRG RET
4	60646	WASHER-BEARING RET
6	110029	WASHER
7	216837	PIN-PK KNIFE SFT MTG
8	257968	SET SCREW 1402 ONLY
9	257974	SET SCREW 1402-2 ONLY
11	327614	STUD-JOGGLER SPRING
12	336146	HANGER-BRG
13	336152	SLEEVE-BRG
14	336323	WASHER-BRG RET
16	364196	COLLAR 1402 ONLY
17	602217	BRG RETAINER
18	602278	SPACER-FD ROLL LWR
19	602280	SPACER 1402-2 ONLY
21	602314	KEY-PULLEY
22	602452	PULLEY-LWR FD ROLL
23	602474	GEAR 1402-2 ONLY
24	602483	PULLEY 1402-2 ONLY
26	602497	KEY-PULLEY MTG 1402-2 ONLY
27	602647	WASHER-BEARING
28	602670	SPACER-LWR FD RL PULL
29	603116	RETAINER-BRG
31	609112	SPRING-EXTENSION
32	609460	STUD-SHIELD MTG
33	615365	STUD-SAFETY CVR MTG
34	1090873	LWASHER

A1	602880	SHAFT ASM-CAM
37	156231	BEARING
38	219743	CLIP
39	602648	RETAINER
A1A	602254	SHAFT ASM-CAM
41	255597	TAPER PIN-PKR KNIFE CAM
* 42	602250	SHAFT-CAM
* 43	602253	CAM
A2	602882	3RD & 4TH LWR FD RL ASM 1402-2 ONLY
46	102691	WASHER
47	156231	BEARING
48	156364	BEARING
49	234321	SCREW
51	336270	HUB
52	602261	SHAFT
A3	602884	FEED ROLL ASM-2ND LOWER
56	156364	BEARING
57	234321	SCREW
58	336153	HANGER
59	336320	CLIP
61	602209	SHAFT
62	1090448	WASHER
A4	603547	CONTACT ROLL ASM-2ND
A4	602885	CONTACT ROLL ASM-2ND
64	336310	COLLAR
		BALANCE OF HARDWARE SHOWN ON ASM A 11
A5	609488	1ST,3RD & 4TH LWR FD RL ASM
66	156231	BRG-FD ROLL
68	156364	BRG-FD ROLL
69	257968	SET SCREW-COLLAR
71	336270	HUB-FD ROLL BRG
72	336310	COLLAR-BRG RET
73	609487	SHAFT-FEED ROLL
A6	609581	PULLEY ASM-CAM SFT
76	129654	SCREW-CAM SHAFT
77	602496	PULLEY-CAM SHAFT

A7	609582	GEAR ASM-CONT RL
81	257972	SET SCREW
82	364155	COLLAR
83	364164	GEAR
84	512508	SCREW
A8	609583	GEAR ASM-FD RL
86	35739	SCREW-GEAR MTG
87	257970	SET SCREW
88	364022	HUB-GEAR
89	364154	GEAR
A9	609584	PULLY & GEAR ASM-CONT RL
91	38359	SCREW
92	336254	COLLAR
93	336359	SET SCREW
94	602230	PULLEY
95	609113	GEAR
A10	609585	PULLEY ASM-CONT RL
97	336254	COLLAR
98	336324	SCREW
99	336359	SET SCREW
101	602230	PULLEY
A11	609778	CONTACT ROLL ASM-1ST
A11	609498	CONTACT ROLL ASM-1ST
106	156364	BEARING-CONTACT ROLL
107	257968	SET SCREW-COLLAR
108	603087	CONTACT ROLL
106	602155	CONTACT ROLL
109	602216	HUB-CONTACT ROLL BRG
111	609122	COLLAR 609778 ONLY
		PARTS NOT INCLUDED WITH ASSEMBLIES
114	602324	BELT-CONTACT RL

UPPER FEED ROLLS ASMS.



FOR REMAINDER OF THIS ASM SEE FIGS18 THRU 30

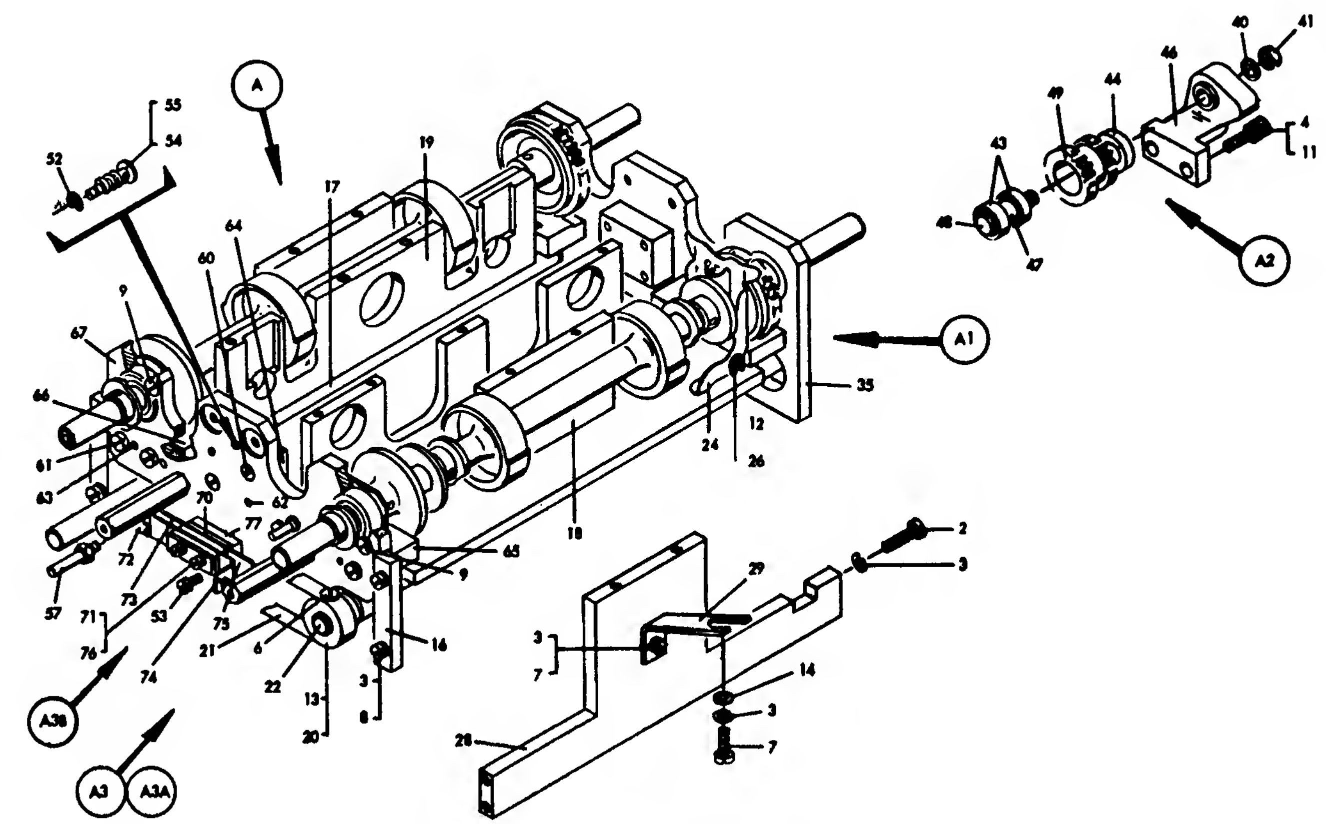
*A		609053	PUNCH TRANSPORT ASM 1402
*A		614021	PUNCH TRANSPORT ASM 1402-2
	2	845	SCREW-BEARING RET
	3	6364	LWASHER-BEARING RETAINING
	4	19944	SCREW-FD RL HANGER
	5	38351	SCREW-BEARING RET
	6	38352	SCREW
	7	55901	LWASHER-BRG RET
	9	150566	WASHER-BRG RET
	10	156364	BEARING-FEED ROLL
	11	160827	POST-SPRING HANGER
	13	238364	SWITCH
	14	257985	WASHER - SW MTG
	16	321483	SCREW-HANGER MTG
	17	336146	HANGER-FD RL
	18	336152	STUD-HANGER MTG
	19	336153	HANGER-FD RL
	20	336320	CLIP-FD RL HANGER
	21	336323	WASHER-HANGER MTG
	23	438553	SCREW-SWITCH MTG

	25	607188	SPRING-HANGER
	26	607358	HANGER-FD RL
	27	607475	SLEEVE-HANGER
	28	608074	POST-SPRING HANGER
	29	609747	SCREW-BRUSH LOCATING
	30	1091508	WASHER-HANGER MTG
A1		607148	FEED ROLL ASM-6TH UPR
	35	58114	SPACER-6TH UPPER FD RL
	36	156364	BEARING
	37	435943	TAPER PIN-GEAR MTG
	38	607150	FEED ROLL-6TH UPPER
	39	607212	GEAR-UPPER FD RL
A2		607689	FEED ROLL ASM-UPR
	45	435943	TAPER PIN-GEAR MTG
*	46	607687	GEAR-FIFTH UPR FD RL
*	47	607688	ROLL-FIFTH UPPER FEED
A3		607691	FEED ROLL ASM-5TH
	50	4327	TAPER PIN
*	51	607121	COLLAR-2ND & 5TH UPR ROL
*	52	607686	GEAR-SECOND UPPER ROLL
*	53	607690	ROLL-SECOND UPPER FEED

A4		607357	HANGER ASM-FD RL
	58	156364	BEARING-FEED RL SHAFT
	59	607358	HANGER-UPPER FEED ROLL
A5		610140	CONT ROLL & SHAFT ASM
	65	845	SCREW-BRG RACE RETG
	66	2903	WASHER-BRG RACE RETG
	67	55901	LWSHR-BRG RACE RETG
	68	257969	SET SCREW-CONTACT ROLL
*	69	607175	CONTACT ROLL
	70	607355	HOUSING-CONT ROLL
A5A		607168	SHAFT ASM CONTACT ROLL
	75	19167	TAPER PIN-GEAR MTG
	76	151720	SET SCREW-COLLAR MTG
	77	156364	BEARING
	78	442823	COLLAR-SPRING RETAINING
*	80	607169	SHAFT-CONTACT ROLL
*	81	607170	GEAR-CONT RL
	82	607171	SPACER-CONTACT ROLL
	83	607172	SPRING-CONT RL CLUTCH

*
NOT RECOMMENDED FOR NORMAL FIELD REPLACEMENT

LOWERING FRAME ASM. I



FOR REMAINDER OF THIS ASM SEE FIGS18 THRU 30

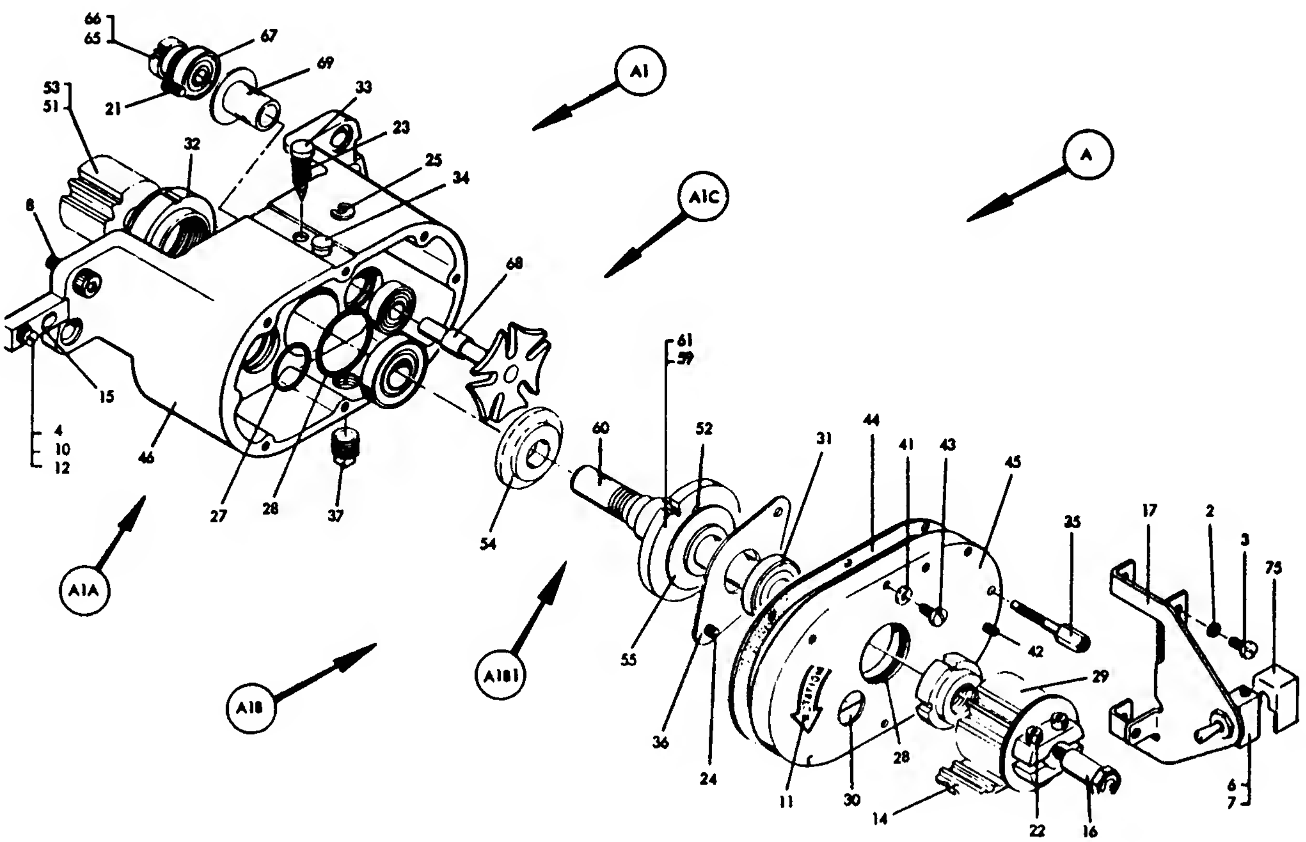
*A		609053	PURCH TRARSPORT ASN 16D2
*A		614021	PUMCH TRANSPDRT ASM 16D2-2
	2	5644	SCREW
	3	6364	LOCKWASHER
	4	9092	LWASHER-IDLER M7G
	6	10170	SCREW-TAPE M7G
	7	38351	SCREW
	8	38354	SCREW
	9	81693	SCREW-BRG RET
	11	104763	SCREW-IDLER MTG
	12	147297	CLIP-SIDE ALIGNER
	13	257970	SE7 SCREW-LWRG SHAFT
	14	257986	WASHER
	16	607199	GUIDE-LOWERING FRAME
	17	607229	BASE-CD GDE
	18	607230	SUPPOR7-CD GDE
	19	607232	SUPPORT - CD GDE
	20	607239	COLLAR-LWR SHAFT
	21	607241	TAPE-LOWERING CAN DR
	22	607246	SHAF7-LOWERING FRAME
	24	607387	ALIGNER-RIGHT SIDE
	26	607678	PIR-SIDE ALIGNER
	28	609768	SUPPORT
	29	6D9771	BRACE

A1		607634	FRAME ASM-R LWRIRG
	35	607636	FRAME-R7 LOWERIRG
BALANCE OF PARTS SHOWN UNDER A3A			
A2		609059	IOLER GEAR ASM
	40	9092	LWASHER-IOLER
	41	11598	RUT-IOLER
*	63	110129	BEARIRG-IDLER GEAR
	66	310781	SPACER
	66	609060	SUPPOR7 CASTING-IDLER
*	67	6D9061	CLAMPIRG SPACER-IOLER
	68	609063	STUD-IDLER
*	69	609064	GEAR-IDLER
A3		610133	LWRG FRAME & IRTLK ASM L
	52	25282	CLIP-DIE VISUAL AID
	53	38265	SCREW-DIE CONTACT NTG
	56	96388	SPRING-DIE VISUAL AID
	55	607D85	PIN-DIE VISUAL AID
	57	6D7243	STUD-LWRG KNOB LOCK

A3A		607514	FRAME ASM LEFT LOWERIMG
	60	337	SCREW-DIE SUPPOR7 M7G
	61	2031	SCREW-BLOCK MTG
	62	173700	7APER PIR-DIE SUPP LOC
	63	216537	7APER PIR-CO GD SUPP LOC
	66	607190	BLOCK-DIE SUPPORT
	65	607197	SUPPOR7-CD GD 2MD LWR
	66	607198	SUPPOR7-CD GD 3RD LWR
	67	607559	FRAME-LEF7 LOWERING
A3B		607196	CONTAC7 ASM
	7D	11900	IMSULA7ION-COMTAC7 SPG
	71	100229	INSULATION-SCREW
	72	106988	CONTAC7-CARD LEVER
	73	107070	CONTAC7-CARD LEVER
	76	161964	TERMINAL-CONTACT
	75	161966	TERMINAL-CONTACT
	76	196835	SCREW
	77	61D185	PLATE-CONTACT MOUNTING

* NOT RECOMMENDED FOR NORMAL FIELD REPLACEMEN7

GENEVA ASM.



FOR RENAINOER OF THIS ASM SEE FIGS18 THRU 30

*A		609053	PUNCH TRANSPORT ASM 1402
*A		614021	PUNCN TRANSPORT ASN 1402-2
•	2	6364	LWASNER - BRKT MTG
	3	38352	SCREW - BRKT NTG
	4	62031	LWASNER-GENEVA BL NTG
	6	121756	SWITCN - CRANK INT
	7	159373	LWASHER-SWITCH MTG
	8	169733	SCREW-GENEVA NTG
	10	251820	SCREW-GENEVA BL MTG
	11	256443	OECAL-ROTATION
	12	510809	WASHER-GENEVA PLK MTG
	14	607656	BELT-TIMING
	15	608203	BLOCK-GENEVA PCS
	16	609426	STUO-CRANK
	17	609427	BRACKET - CRANK INT SW

A1		607050	GENEVA ASM
	21	10170	SCREW BRG RETAINING
	22	129654	SCREW PULLEY MTG
	23	151405	SPRING TIMING PIN
•	24	234317	SCREW-BEARING RET
	25	264641	CLIP SPRING
•	27	607051	O RING GENEVA SFT
•	28	607052	O RING GENEVA OR SFT
	29	607063	PULLEY-TIMING BELT
•	30	607066	LENS OIL LEVEL
•	31	607067	BRG GENEVA OR SFT
•	32	607074	LOCKNUT BEARING
•	33	607075	TIMING PIN GENEVA
	34	607174	OIL CUP GENEVA HOUSING
	35	607901	STUO-CRANK SW BRKT MTG
•	36	610066	SLINGER-OIL
	37	610717	PLUG ORAIN
*A1A		607053	NOUSING & COVER ASM
	41	6364	LWASHER COVER MTG
	42	257702	TAPER PIN COVER MTG
	43	355369	SCREW COVER MTG
•	44	607054	GASKET CVR REAM SPACER
•	45	607055	COVER GENEVA
•	46	607056	HOUSING GENEVA ORIVE

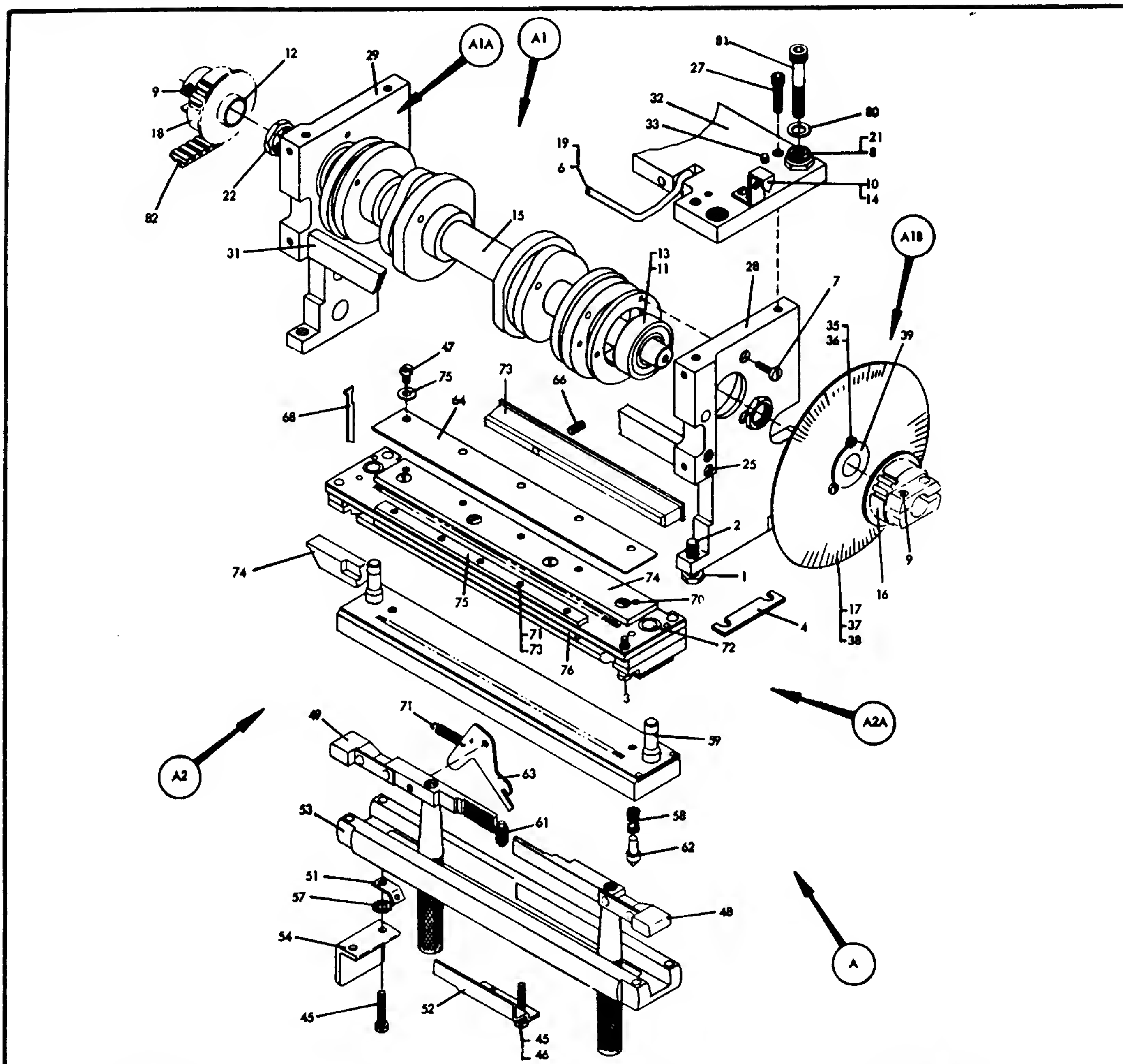
*A1B		607057	SHAFT ASM-GENEVA ORIVE
•	51	255597	TAPER PIN PULLEY NTG
•	52	607062	PIN-GENEVA ORIVE
•	53	607809	PULLEY-GENEVA TIMING
•	54	610075	SLINGER GEN OR SHFT OIL
•	55	610076	SLINGER GEN SNFT FRONT
*A1B1		607059	OISC ASM GENEVA ORIVE
•	59	257005	TAPER PIN WHEEL MTG
•	60	607060	SNAFT GENEVA ORIVE
•	61	607061	OISC INTERMITTENT OR
*A1C		607068	SHAFT ASM-GENEVA WHEEL
•	65	4327	TAPER PIN GEAR MTG
•	66	607069	GEAR GFNEVA SFT
•	67	607070	BEARING
•	68	607071	SNAFT GENEVA
•	69	607072	SPACER GENEVA SFT

PARTS NOT INCLUOEO WITH ASSEMBLIES

75	607268	COVER-TIMER SWITCN

*NOT RECOMMFNOEO FOR NORMAL FIELO REPLACEMENT

PUNCH UNIT ASM. II



A		6D9D72	PUNCH UNIT ASM
	1	6SD3	NUT
	2	128543	SET SCREW
	3	133742	SCREW-STRIPPER MTG
	4	437964	SHIM
A1		6D7D42	CAMS & BAIL ASM
	6	11587	PIN-PUNCH UNIT HANDLE
	7	52607	SCREW-BEARING RET
	8	7D9SD	NUT-BUSHING ADJ
	9	129654	SCREW-PULLEY CLAMP
	1D	38261	SCREW-POINTER MTG
	11	2D4326	BEARING-CAM SHAFT
	12	437531	SPACER-PULLEY
	13	437682	RETAINER-BEARING
	14	61D166	POINTER-TIMER
	15	6D7D45	CAM-PUNCH
	16	607151	PULLEY-CB DRIVE
	17	257969	SET SCREW
	18	607159	PULLEY-PUNCH DRIVE
	19	607474	HANDLE-PUNCH UNIT
	21	6D777D	BUSHING-ADJUSTING
	22	6D8029	NUT-CAM SHAFT BRG
A1A		6D7157	SIDE FRAME ASM
	25	15D0	SCREW SPACER BAR MTG
	27	1D4763	SCREW TOP PLATE MTG
	28	437623	FRAME FRONT SIDE
	29	437624	FRAME REAR SIDE
	31	437716	TIE BAR SIDE FRAME
	32	607158	PLATE TOP MTG
	33	122856	TAPER PIN TOP PLATE MTG
A1B		6D7154	DIAL ASM-INDEX
	35	38261	SCREW-INDEX MTG
	36	257985	WASHER-INDEX MTG
	37	437289	PIN-ROLL
	38	607155	INDEX-TIMING
	39	607156	HUB-INDEX DIAL
A2		4376D1	DIE & STRIPPER ASM
	45	2384	SCREW BLOCK DIE REINF
	46	6318	LWASHER DIE PLATE REINF
	47	42026	SCREW PUNCH STOP SPRING
	48	112537	RACK-FRONT
	49	112538	RACK-REAR
	51	112542	ANCHOR SPRING
	52	112611	COVER ASM RACK
	53	112613	BLOCK DIE PLATE REINF
	54	133686	PLATE DIE ADJ ANGLE
	57	139450	WASHER DIE ADJ ANGLE
	58	141492	SPRING RELEASE PIN
	59	151908	STUD DIE GUIDE
	61	151911	PINION RACK
	62	151914	PIN RELEASE
	63	175169	INTERPOSER ASM
	64	437683	STOP PUNCH
	66	25199D	SCREW-GREASE RETAINING
	68	60D963	PUNCH
	71	6D2174	SPRING INTERPOSER
	73	61D168	GREASE RETAINER
	74	610171	GREASE RETAINER
	75	1D9D873	WASHER PUNCH STOP SPRING
A2A		437696	STRIPPER ASM GUIDE
	7D	25625	SCREW PUNCH SPRING STOP
	71	60646	LWSHR STIFFENER MTG
	72	151907	BUSHING DIE GUIDE
	73	186758	SCREW-STIFFENER MTG
	74	437684	SPACER PUNCH STOP
	75	437698	STIFFENER PUNCH GUIDE
	76	441745	STIFFENER GUIDE PLATE

PARTS NOT INCLUDED WITH ASSEMBLIES

8D	130435	WASHER-PUNCH UNIT MTG
81	186934	SCREW-PUNCH UNIT MTG
82	6D7578	BELT-TIMING

ENGINEERING CASE LIBRARY

ECL 6

INTERNATIONAL BUSINESS MACHINES CORPORATION (D)

Need for a New Automatic Card Punching Machine

While International Business Machines Corporation has cooperated with Stanford in encouraging the development of this course material and in supplying basic information and documentation, the company has not reviewed the course manuals and has had no part in their preparation and therefore does not necessarily concur with any opinions expressed or attest to factual accuracy. IBM wishes explicitly to avoid such intervention in order to allow complete editorial freedom to the University.

Prepared in the Design Division of the Mechanical Engineering Department, Stanford University, by Bernard Roth and Karl H. Vesper, as a basis for student projects with financial support from the National Science Foundation.

Mr. Ekks[1], the Engineering Manager of a large product section at IBM's San Jose Development Laboratory, was becoming increasingly convinced that his department would soon be called upon to design a "serial" automatic card punching machine. A "serial" machine would be one in which the short edge of the card led during processing. All previous IBM automatic punching machines had been "parallel" machines which passed cards through sideways, leading with a long edge.[2] To punch serially, the new machine could operate with as few as twelve punches instead of the eighty required on parallel machines. Lower cost was a primary objective of the overall system in which the new serial punch would be required.

It was expected that a requirement in designing the new machine would be that it be put into production as soon as possible. For this reason, there probably would not be time to experiment with radical departures from past techniques of handling and punching cards. Mr. Ekks' feeling was that the most difficult aspects of the design would center around the punching section of the machine, and that within this section it would be best to plan on stepping the card with feed rolls past a single column of twelve punches and dies. He was, however, open to other suggestions.

New Product Ideas

Ideas for new machines came to Mr. Ekks' attention from several sources. A major source was the IBM sales force. Constantly calling on existing and prospective customers, the salesmen frequently encountered needs which suggested development of new products. Another source of ideas was the engineering organization itself, in which the search for better ways of doing things was a way of life. Mr. Ekks' own experience, which had included many years as a user of IBM equipment working for the U. S. government, was another source. A conscious effort on the part of management throughout the company was made to encourage innovation, and awards had been established to reward original thought wherever it occurred in the organization.

One of the engineers in Mr. Ekks' department described the flow of new product ideas in the Unit Record Systems Department as follows:

---

[1] A disguised name.

[2] A keypunch machine passes cards serially because the information conventionally appears on cards serially. The keypunch, however, is generally considered to be a manually operated machine and not automatic. Keypunches have, on a few occasions, been coupled into computer systems to operate automatically. They were, however, quite slow (20 columns per second) and not considered satisfactory for such use.

"We are usually flooded with formal requests for new machines from all over the company. We can't possibly carry them all out, and not all the ideas that come to us are worth the expense of further development. To screen them, the department has about a dozen people who spend full time just sifting and analyzing the market demand of proposed new products.

"Several of those who review the ideas are former salesmen who by experience are familiar with customers' needs and desires, and some of them are former customers themselves. They often visit existing or potential customers and ask for reactions to the new ideas, perhaps asking whether a certain speed and flexibility would be attractive at a certain price.

"Those ideas which seem to offer particular promise are sometimes made the subject of "case studies". A case study is a written analysis evaluating a hypothetical new computer system in terms of one or more "typical" prospective customers. In the study, the advantages of the proposed system are weighed against its predicted cost. If this comparison favors the new system and if there appear to be many such "typical" customers to whose needs it is well suited, we engineers will be asked how soon we can complete the design.

"Usually, we are first asked for less performance than we can give on some characteristics of the machine and more than we can give on others. We point this out, and the argument goes back and forth. There is usually a tradeoff to be struck, for instance, between performance and cost. Sometimes, to free up the bottleneck of an overall system, however, the cost of a key machine may be allowed to go somewhat higher than desired.

"Finally, we reach some agreement on what can be done, and engineering formally promises the company a certain design. Our promise has to include performance specifications and costs on the machine we are to design, and a time schedule as to when the machine will be ready for production. Then we go to work designing, testing, and redesigning to keep the promise.

"We're pretty careful to come through on these promises. Competition is rough in the computer industry, and the promises we make are serious business to the company."

Reasons for the Serial Punch

The serial punch was expected to be required as part of a new computer system for which market demand seemed to be developing. A main objective of the system would be lower price. The system would be designed for customers large enough to take advantage of an automatic computer but too small to require the full capacity of existing IBM computer systems such as the 1401. There were already some smaller computers on the market, but these were generally either non-automatic, requiring continual operator control, or else they were designed for scientific rather than business applications. Computers designed for scientific use generally could perform more complex computations faster on smaller quantities of data, whereas business computers were used more to perform simpler computations on larger amounts of data. Therefore, high speed of input-output units tended to be more important on business computers. The serial punch would be intended for use on automatic computers for business applications.

Use of the serial mode of punching was expected to reduce cost of the computer system in two ways: (1) the punching and reading mechanisms could be made more cheaply, and (2) the computer logic system required would be simpler. By reducing the number of punches and their related mechanisms from 80 sets down to 12, there would be reduction not only of the number of parts, but also of the stresses on the framework supporting the punches. Operating serially would also permit the number of reading elements to be reduced.

A much greater saving, however, would result from simplification of the logic in the computer which would be made possible by serial punching. The messages on punched cards were generally written serially. Only by punching serially could the punch be fed computer output character by character from beginning to end as the card was processed. In parallel punching the computer had to store all the information to be punched on a given card before starting to punch, since parallel punching caused the last part of the message to be punched at the same time as the first part of the message. To punch parallel the machine operates in a fashion analogous to typing all the letters from top to bottom of a written page one column at a time, rather than writing one line at a time. To store the cardfull of information before punching parallel, the computer requires additional memory, which is expensive. By punching serially the expense of this extra memory can be eliminated.

Flexibility can also be added by punching serially rather than parallel. Reading and punching functions can be combined by placing reading sensors just ahead of the punching section of the machine. Then the card can enter, be read, then be stopped while the computer performs calculations on what has been read. When these calculations are done the card can again be started and punched with additional information, so the whole sequence occurs in one pass. For instance, if the first few columns of the card contained the value of some separate items on a utility bill, the computer could read these items, calculate the total bill and punch in the total on a later column of the card.

In the opinion of the marketing department speed of operation would be important in selling the new machine. Their opinion was that it would be desirable to operate at least as fast as existing machines such as the 1402 which had a throughput of 250 cards per minute. If still higher speeds could be realized, they said, so much the better, although costs should also be kept down. As a rule of thumb, marketing estimated that at speeds above 100 cards per minute, the value of increases in speed would be proportioned such that a doubling of a speed would be worth roughly a 40% increase in cost.

Engineering Requirements

It was readily agreed by the engineers, based on past experience, that there would be no great problems involved in designing the infeed to accept a deck of cards and move them one at a time to the positions where the punching section would take over. Nor was it expected to be a problem to design the card outfeed to accept cards from the punching section and restack them for removal by the operator. The most difficult part of the design was expected to be that of the punching section itself.

For control, the new punch would have to accept only electrical signals, as did other automatic punches. There should also be included an automatic check to send a signal to stop the machine in case any hole was either skipped or punched in the wrong place. The punch would normally be used for Hollerith code, but because other codes might also be required, the punch should have the capability of punching all twelve rows in one pass.

One engineer observed that to be able to stop, perform calculations, and restart on command, the punch feed would need some kind of electrically triggered clutching mechanism for disengaging from the main power shaft temporarily. It was presumed that mechanical power would be available through a toothed belt from a continuously running fractional horsepower motor also used to drive other mechanical components such as picker knives, jogglers, infeed and outfeed. In all previous punches, motors of less than a half horsepower had been fully adequate, but a larger motor could be provided without difficulty if required.

Another requirement of the machine, the engineer continued, would be that it have two sequences for passing cards, one for reading and one for punching. For reading, the cards normally passed the reading sensors at high and continuous velocity, whereas in punching they usually advanced in steps, stopping for each punch stroke. Cards were read in existing machines as fast as 800 per minute, but punched much slower.

"Now, it seems to me," replied another engineer, "that we're starting to define our design requirements. Maybe we should carry this further. What should the rest of our design objectives be, and what problems do they suggest? How might we feed the cards for reading and punching, and how might we take care of the clutching? Can we just take one of the tried and true old parallel machines, remove 68 of the punches and turn it around sideways? If not, why not? If so, what other modifications would we have to make?

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ECL 7

INTERNATIONAL BUSINESS MACHINES CORPORATION (E)

Expected Design Problems on the Serial Punch

Prepared in the Design Division of the Mechanical Engineering Department, Stanford University by Bernard Roth and Karl H. Vesper, as a basis for student projects with financial support from the National Science Foundation.

Higher speed in the serial machine could be expected to further increase the danger of shortened life unless adequate steps were taken to reduce wear.

Problems of wear in the past had led to rules of thumb that it was generally best to use ball bearings for all shafts and that tungsten carbide would be advisable material for making the punch and die. From experience it had been determined that the punch should over-travel at least 0.007 inches into the die to assure complete cutting.

On the other hand, not all the design constraints were foreseen to be more severe for the serial punch than for parallel machines. For instance, the reduction in the number of punches, magnets and related parts would reduce overall complexity and take less room. The requirement to locate only 12 holes on 1/4 inch centers instead of 80 holes on 0.087 inch centers would allow more space for each punching mechanism.

The total space required for the punching mechanism, however, was not expected to be limited. The infeed and outfeed mechanisms could usually be easily adapted to requirements of punching section, and the dimensions of the overall machine were not expected to be limited. Neither was overall weight of the assembly expected to be important within the general range of previous punches.

No problems of noise were anticipated. As one engineer put it, "These machines are expected inevitably to be noisy. The ball bearings alone will make a fairly loud whirring noise. Addition of the motor, gears, picker knives and jogglers will make still more noise, and the cards themselves will add quite a popping clatter. With all these noises to start with, the noise of the punching itself doesn't make all that much difference. Noise doesn't add arithmetically."

As the first step in designing a new card handling machine, I.B.M. engineers usually would map out the entire sequence of operations on the card and determine the timing of each step. One way used to plan timing was to list the operations to be performed and simply divide the total available cycle time among the items of the list. Another approach was to plot graphically the movement of the card versus time. Both the leading and the trailing edges of the card would be plotted with distance expressed in full scale and time expressed as rotational degrees of a continuously revolving power shaft.

Once timing has been apportioned, the work would begin of designing physical characteristics of the machine's component parts. The resulting mechanisms would then be analyzed to determine whether they could really be expected to meet the performance required of them. Often as a result of such analysis on previous machines it had been necessary to rearrange the timing sequence and repeat the design process.

I.B.M. engineers concluded that design of the serial punch would pose some quite different problems than those of the older parallel machines and that it would not be possible simply to modify an older parallel punch slightly and expect it to do the required job. Within the time limitations of the project and the cost constraints of the desired machine they also did not think it would be possible to punch serially at 250 cards per minute with the necessary accuracy. After some discussion, it was decided that the design would be aimed at the "highest practicable" speed, with expectations that around 100 cards per minute would result.

Design constraints around which the greatest difficulties were expected included the following:

1. Speed - Since by definition serial operation would pass cards the length of 80 holes instead of 12, the velocity of the card would have to be much higher for throughput comparable to a parallel machine. Existing parallel machines, however, were already operating close to their maximum speeds, and attempts to push them faster resulted in shortened life and inferior performance.

2. Card Indexing Accuracy - By moving through 80 punch locations instead of 12, it was expected that the tolerance buildup would be more difficult to control in locating holes properly.[1] Buildup on the 12 punching positions of parallel machines was at present satisfactory, but didn't leave much accuracy to spare. Moreover, if the parallel machines were operated above design speed, the indexing accuracy diminished and the resulting cards became unacceptable.

3. Wear - The life of the new machine was required to be comparable to that of the other peripheral equipment made by IBM. Moreover, within the machine it was considered desirable that all wearing parts last the same length of time. The life of IBM punching equipment typically was aimed to be at least 5 to 6 years, which could mean hundreds of millions of cycles, depending on how continuously a customer used it. High reliability was considered extremely important.

With the number of punches reduced, the frequency of use of each punch would be proportionately higher. Serial punching would also mean that one of the punches, the one on the zero row, would be used much more than the others. In Hollerith code, the zero row in cards could be expected to require several times as much punching as any other row for two reasons: First, the numeral zero occurs in numbers over three times as frequently as any other numeral. Second, some users punch zeros for all columns in which no other information is punched. The zero thereby serves as a check to assure that no column has been overlooked in punching. Thus, in a column of figures some of which run to six digits, the number one thousand might be entered as 001000, rather than simply as 1000. The extent of the additional demand on the zero punch to be expected from this practice was not known. With parallel punching, there was no comparable emphasis known to exaggerate wear on a particular one of the punches

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[1] For accuracy requirements of the hole locations, see the "Note on Punched Cards" (E.C.L. 2), Exhibit 7.